Sky and TELESCOPE

Solar telescopes at Sacramento Peak

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Venus as a Radio Source

The Sacramento Peak Observatory

Japanese Observations of a Major Change on Mars

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Vol. XV, No. 10 AUGUST, 1956

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Venus as a Radio Source

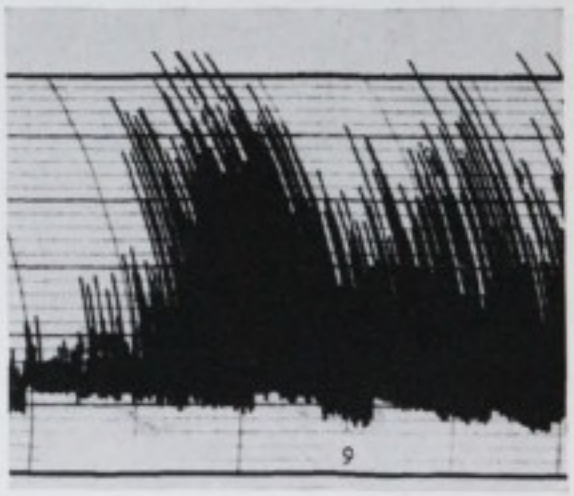
RADIO noise originating on the planet Venus has been detected by astronomers working independently at Ohio State University and the Naval Research Laboratory, Washington, D. C. Venus thus becomes the second planet to be observed at radio wave lengths, only a year after the first such observations of Jupiter (*Sky and Telescope*, June, 1955, page 324, and June, 1956, page 358). The Venus observations, however, pertain to two distinct phenomena.

At the Naval Research Laboratory, radiation from Venus at a wave length of 3.15 centimeters has been recorded repeatedly since May 2, 1956, with the 50-foot radio telescope, by C. H. Mayer, R. M. Sloanaker, and T. P. McCullough. The observations consisted of comparisons, made 30 times per second, of the radio brightness of Venus with that of the background sky. On May 2nd, the power from Venus collected by the antenna was near the lower limit of detectability, but during the following weeks it increased steadily, at a rate consistent with the growing angular diameter of Venus as it approached the earth.

The significance of the Washington observations is straightforward. Venus, like any relatively cool body absorbing radiation from the hot sun, will re-emit it as thermal energy, mainly in the infrared, but also to a lesser amount at radio frequencies. Infrared measurements of this emission from Venus were first made over 30 years ago, and it is now being detected by radio techniques. The brightness of Venus at 3.15 centimeters corresponds to a source temperature in excess of 350° absolute, according to a tentative estimate by the NRL radio astronomers. They stress, however, that this temperature cannot be assigned to the surface of the planet without additional information.

The fluctuating bursts of radio noise

(Continued on page 444)

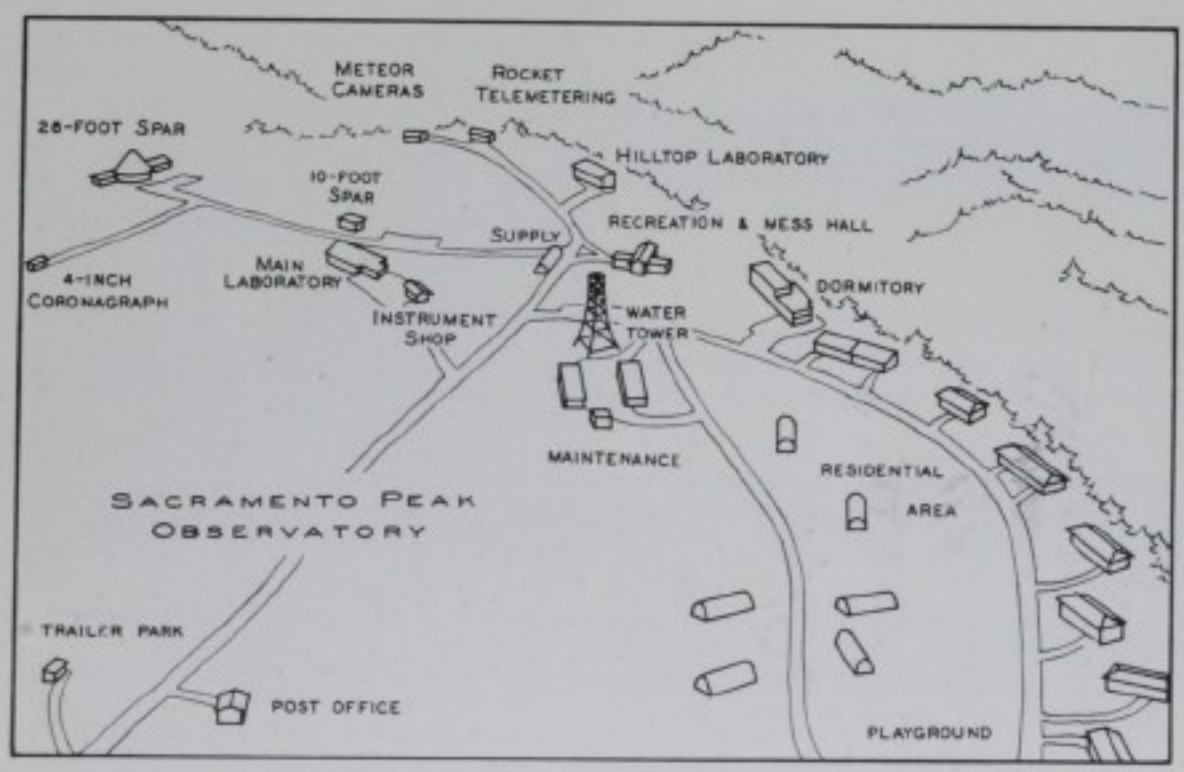


Radio noise from Venus is shown by this 1¼-hour portion of a record obtained by John D. Kraus, on May 23, 1956. The sharp bursts last about one second or less. Ohio State University tracing at 11 meters wave length.

An aerial view of Sacramento Peak Observatory, in southern New Mexico. As recently as 1947 the mountaintop was unoccupied, but since then the community of Sunspot, N. M., has grown here, devoted to a massive and far-reaching attack on the problems of solar astronomy and solar-terrestrial relationships. The view is toward the southwest.

The Sacramento Peak Observatory

JOHN W. EVANS, Superintendent, *Sacramento Peak Observatory, Air Force Cambridge Research Center*



In this key chart are identified the principal buildings in the aerial photograph of the Sacramento Peak Observatory at the top of this page.

SOLAR-TERRESTRIAL research is today a major field of astronomy. It was opened a century ago by the discovery of a close correlation between sunspot numbers and magnetic activity on the earth. Later, when radio communication came into general use, it was soon painfully apparent that there were other terrestrial responses to solar activity, including very troublesome radio blackouts.

Fortunately, radio itself has proven to be a powerful tool in indicating that most of the observed disturbances from solar activity are the result of changes in the ionosphere. This is a layer in the upper atmosphere of the earth where a small fraction of the air molecules is ionized by solar ultraviolet radiation, as well as by showers of electrons and protons emitted by the sun.

One of the aims of the Geophysics Research Directorate of the Air Force Cambridge Research Center is to learn more of the nature of the ionosphere and its changes. Since the sun is ultimately

Delicate structure appears in this green-light photograph of the inner corona on October 31, 1955. The 6-inch coronagraph was used, with a birefringent filter that passed only light within a band a few angstroms wide.

responsible both for the existence of the ionosphere and for its disturbances, an important part of this investigation is a study of solar activity, and of the physical processes that produce violent fluctuations in the sun's emission of ultraviolet light and ionizing particles. Accordingly, the Air Research and Development Command has established the Sacramento Peak Observatory (formerly Upper Air Research Observatory) as a part of the Geophysics Research Directorate. Our program is devoted wholly to studies of the sun, on the assumption that solar activity must be explained before we can understand the geophysical responses to it.

The observatory is at an elevation of 9,200 feet, on Sacramento Peak in southern New Mexico, about nine air miles southeast of Alamogordo, but 36 miles by road. This isolated spot was chosen because of the clarity of the sky for observations of the corona, the sun's faint, outer atmosphere. Here the permanent community of Sunspot, N. M., has come into being over the past few years, with one purpose in life—solar research. The present population of Sunspot is about 100, including wives and children. The astrophysicists and observers are effectively aided by Air Force personnel from nearby Holloman Air Development Center.

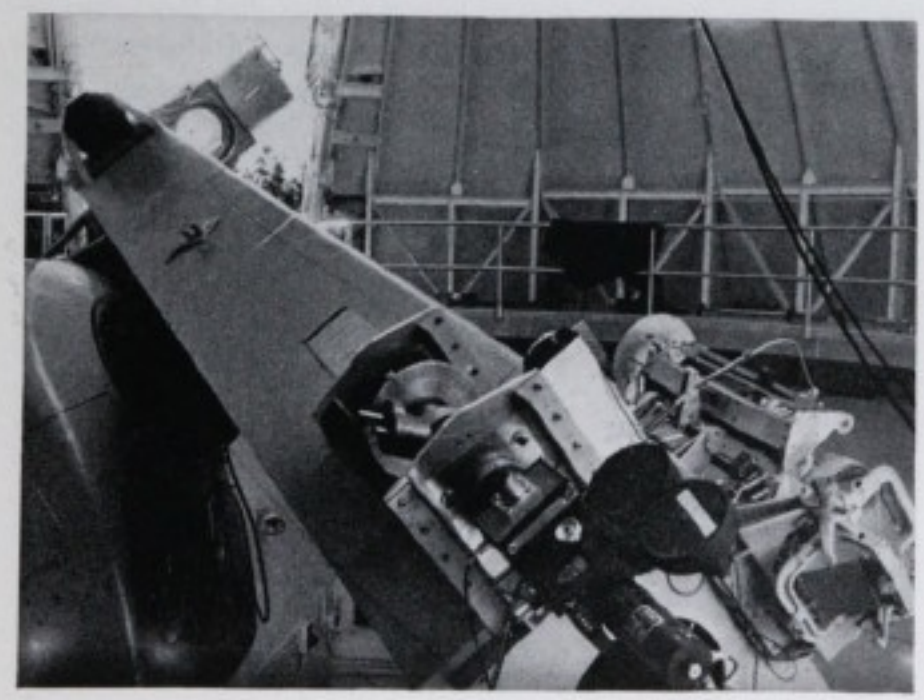
As the aerial photograph shows, the mountaintop has structures of many kinds, ranging in appearance from a water tower (near center) to the conical turret of the 16-inch coronagraph (upper left). There are residences for the scientific staff and military personnel, a dining hall, post office, and the other facilities that make an independent community. A well-built road leads to Sunspot from state highway 83, which climbs to the high country from U. S. 54 north of Alamogordo.

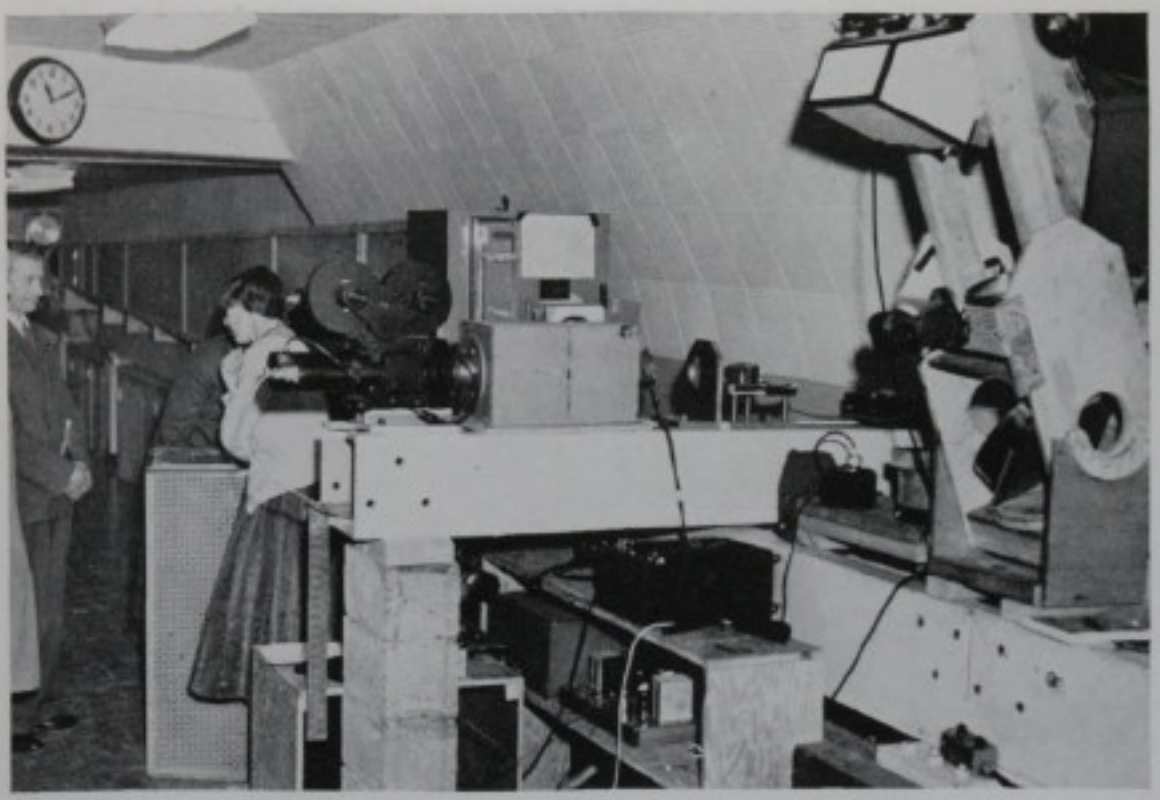
With this article are pictures of some of the instruments now in operation on the peak. They include a 4-inch coronagraph and spectrograph, used for daily observations of the coronal spectrum with a dispersion of nine angstroms per millimeter; a 6-inch coronagraph mounted on a 10-foot spar for motion pictures of prominences and the corona through a birefringent filter of three angstroms band width; also on the 10-foot spar are a 2½-inch flare patrol camera and a sunspot telescope.

But the principal optical equipment of the observatory is the cluster of telescopes, all of which can work on the sun at once, that are carried on the 26-foot spar housed under the turret shown on the front cover. At present it carries a 15-inch telescope for taking large-scale motion pictures of the chromosphere and prominences, and a 16-inch coronagraph, the largest in the world. Another of this size is planned by the High Altitude Observatory at Climax, Colorado. Situated some 450 miles apart in nearly the same longitude, these instruments will have similar programs, with the hope that when one is inactivated by cloudy weather the other can still operate.

The single rugged mounting of the 26-foot spar and its protective turret provide for a fairly large number of instruments, both permanent and experimental. The 9¼-ton spar is simply a rectangular box of 32-by-40-inch cross section, made of ⅜-inch steel plate. It has a special internal supporting system, similar in principle to the mechanical flotation of the mirror of the 200-inch telescope. The declination bearings are inside the spar, consisting of two pairs of SKF angular-contact ball bearings. As it is to be used

Right, the 26-foot spar has an early version of the tubeless chromosphere telescope on its near side, and the 16-inch coronagraph on top. In another view, below, the 15-inch telescope, with its lens covered, has its present form; and more detail shows of the coronagraph occulting disk assembly and prisms.





In the observing laboratory, light that has been reflected down the polar axis of the 16-inch coronagraph enters at the upper right. It passes downward through an image-forming lens to an optical flat (partly seen inside the wooden yoke) which directs it horizontally to the left. The 13-meter spectrograph extends from the upper center of the picture to the extreme left; the grating is located at the far end of the tunnel. At the near end, part of the plateholder is seen; the slit beside it is hidden.

only for solar work, the spar is restricted in declination to the region of the sky extending 25 degrees on either side of the celestial equator.

The spar is carried on a massive hollow polar axis with an oil flotation system, also like that of the 200-inch telescope. It is driven in right ascension by a rather unconventional arrangement of smooth rollers in friction contact, with successive speed reductions back to a little motor of about 2½ mousepower (one mousepower equals 1/10,000 horsepower), some three inches long and 1½ inches in diameter. Fast motion is provided by two ¼-horsepower motors through rubber tires bearing on the 60-inch primary drive wheel mounted on the polar axis. Hence there are no gear teeth, and consequently no backlash in the setting or the drive.

The spar is automatically guided on the sun by an electronic servo system actuated by four small photoelectric cells. A 4-inch lens of 25-foot focus forms an image of the sun on a slightly undersized metal occulting disk, around which the cells are arranged. If the sun drifts, the cells no longer are equally illuminated, and corrections are introduced into the right ascension drive motor and in the declination setting. The accuracy in guiding by this method is limited solely by the quality of the seeing. The effects of refraction and misalignment of the polar axis are automatically compensated.

The 15-inch telescope is tubeless; its objective (on loan from Harvard) is a simple lens, quite satisfactory for observations in monochromatic light, which was figured by James Gagan, a well-known Boston amateur telescope maker. Following the occulting disk in the optical system is a beamsplitter giving four images; behind this comes a birefringent filter centered on the hydrogen-alpha line, with a three-angstrom passband. Next there is a lens system to form the image of the chromosphere on 35-mm. motion picture film, to a scale of about 20 centimeters for the sun's diameter. For accurate photometric calibration, a series of squares of graduated density can be superimposed on the film, so the brightness of the chromosphere or a prominence can be measured in terms of the brightness at the center of the solar disk. This camera was first used in November, 1953, but changes were made and it did not assume its present form until July, 1955. The pictures by Richard Dunn in the February, 1956, issue of *Sky and Telescope*, including the front cover, were made with this instrument.

On the top or north surface of the 26-foot spar is mounted the 16-inch coronagraph, also tubeless, which began operation about a year ago. The single-lens objective of about 25 feet focal length images the sun on an occulting disk of variable diameter at the lower end of the spar. This disk is supported on a two-foot stem extending from the center of the field lens behind it, so there are no shadows from supporting members. Following the field lens is a pair of 6-inch prisms, which reflect light back inside the spar up to a flat quartz mirror, at the intersection of the polar and declination axes.

This mirror sends the light down the hollow polar axle through a secondary lens system into the observing laboratory. James G. Baker's design of this secondary system corrects the chromatic aberration of the primary lens so well that the secondary color is only about one sixth that of an equivalent conventional achromatic lens! The 16-inch coronagraph can be used both for limb objects and the solar disk itself. For the latter work, the field lens carrying the occulting disk is replaced by an unobstructed field lens.

In the observing laboratory, the image from the 16-inch coronagraph can be adjusted to any desired diameter by choosing an appropriate final lens for the secondary optical system, and the light can be directed into any one of a number of

Left: This is one of the very few published photographs of the chromosphere at the limb of the sun in silhouette against a bright prominence. This picture was made with the 16-inch coronagraph in hydrogen-alpha light.

Right: Beside the plateholder of the 13-meter spectrograph is its slit assembly, which Henry J. Smith is adjusting.

This 23-minute record of the life of a sunspot region shows the development of a small, bright flare above, and a "high-speed-dark" feature to the right. The pictures were taken on May 18, 1956, at 13:59, 14:03, 14:11, 14:16, and 14:22 UT, with the 16-inch coronagraph. A Lyot filter with an 0.65-angstrom passband was used for these H-alpha photographs.

accessory instruments, as described here.

The most important of these in present use is a powerful Littrow spectrograph of 13 meters focal length constructed by the Jarrell-Ash Co. Its slit is four inches long, made by R. V. Jones of the University of Aberdeen, Scotland, and generously presented to the Sacramento Peak Observatory as a gesture of international good will. A wide variety of gratings can be used, giving dispersions from 0.8 to 15 millimeters per angstrom. The plateholder takes plates of any size up to 4 by 30 inches.

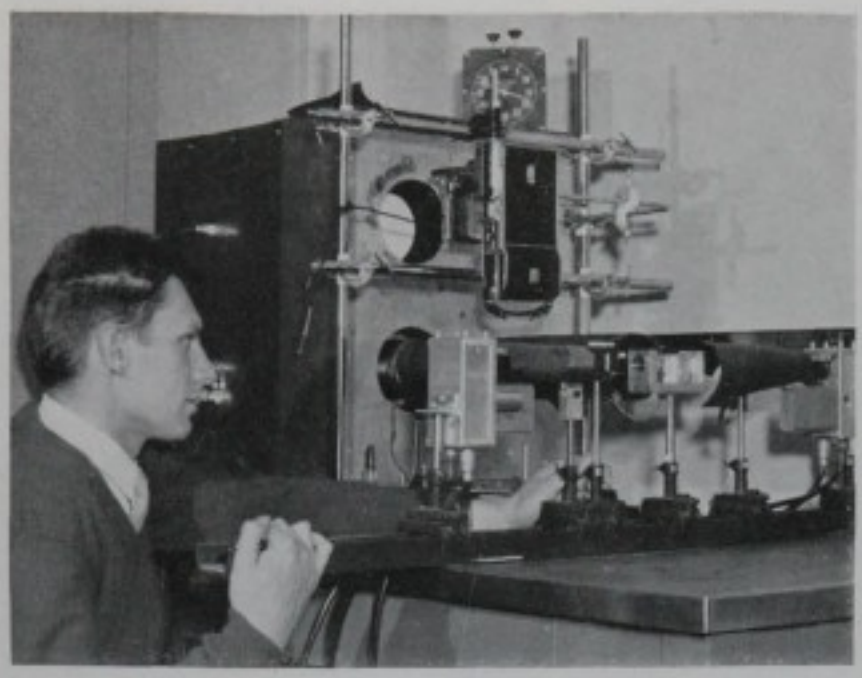
In front of the plateholder is a system of hinged mirrors, which can be swung into position to divert the spectrum into an eyepiece, to a photoelectric photometer, or to a fixed prism system which sends the light back to the grating for a second dispersion, giving the final spectrum twice the scale of that of a single reflection from the grating. The principal use of this double-pass system is the photoelectric measurement of line profiles, especially the shapes of the bottoms of deep absorption lines.

An accessory to the spectrograph is a Lyot birefringent filter of 0.65-angstrom passband, mounted to permit the observer to view the sun in hydrogen-alpha light and to center objects of interest, such as flares, on the slit of the spectrograph. By pressing a button he can photograph the relative position of the slit and the object under observation. The other major accessory for the observing laboratory is a powerful spectroheliograph now under construction. This unconventional instrument is really two spectrographs back to back, arranged so a slit between them isolates the desired line of the spectrum. The second spectrograph almost exactly cancels the dispersion of the first; thus an undispersed monochromatic image is formed on the plate with sharp definition regardless of the slit width.

Small solar patrol instruments are an important part of the Sacramento Peak Observatory's armament, and three of them are carried on the 10-foot spar, a small-scale counterpart of the 26-foot, also photoelectrically guided. The 2½-inch flare-patrol camera takes a hydrogen photograph of the whole sun on 35-mm. film once every five minutes, whenever the sky is clear. Any flare lasting more than five minutes is thus recorded. A reflex mirror permits the observer to see the solar disk in hydrogen light between exposures.

The 6-inch coronagraph is used for patrolling the east and west edges of the sun within 60 degrees of the solar equator. Its purpose is to record all prominences in the active sunspot regions of the sun. If the occurrence of flares is actually closely associated with that of prominences, then we can hope to find an index to the flare productivity to be expected of a given sunspot group. Since flares are the most vigorous sources of radio fadeouts on the earth, such an index would be useful in

Mounted on the left side of the 10-foot spar is the flare-patrol camera. On top of the spar is the 6-inch coronagraph used for coronal and prominence motion pictures. The square box at the upper end of the spar contains the coronagraph lens. The long "dew caps" are actually to shield this lens from dust. At the lower end of the spar, the L-shaped enclosure contains the occulting disk; two right-angle prisms bend the light back up the spar into the camera, passing through a three-angstrom birefringent filter in the cylinder. The observers are Harry Ramsey, left, and Howard DeMastus.



Left: Edwin Dennison is operating the isophotometer, a device which automatically scans a photograph of the corona, for example, and traces on a chart the contour lines of equal coronal brightness. Only two minutes are required for what had been a lengthy and troublesome chore by older methods.

Right: George Schnable is using the 4-inch coronagraph and spectrograph for routine daily observations of the sun's corona.

predicting periods in which fadeouts are likely.

The third instrument on the spar at present is a 6-inch telescope with a wide-field eyepiece: the sun is viewed by projection. The numbers, sizes, and positions of all sunspots and faculae are recorded daily.

Each day at Sacramento Peak the intensities of the coronal spectrum lines at all position angles around the limb of the sun are recorded with the 4-inch coronagraph. The 8-foot equatorial spar that carries it is the oldest permanent installation at the observatory, dating back to the summer of 1949. From the first, this has been one of the most productive coronagraphs in existence. By means of a 6-foot Littrow spectrograph, it records the principal coronal lines on 4-by-10-inch plates, at a scale of nine angstroms per millimeter. A Dove prism allows rotation of the solar image between exposures, eight of which cover the entire circle of the sun's limb.

The many active solar telescopes at Sacramento Peak collect photographic observations in such large quantity that rapid, automatic measurement of the plates and reduction to numerical data are necessary. This problem is particularly important at an isolated observatory such as ours. Devising the automatic equipment calls for much ingenuity and experimentation.

Our first device of this kind is an isophotometer, which scans a photograph of the corona (or of a prominence or flare) and draws a chart showing contour lines of equal brightness. Such a chart is like a topographic map, except that the contours represent levels of light intensity rather than different heights above sea level. The instrument can produce a complete light-contour map in less than two minutes.

Another indispensable aid is a very sensitive microphotometer: when this scans a negative it automatically translates photographic densities into the original light intensities. The measurements are traced on a chart or printed on a tape.

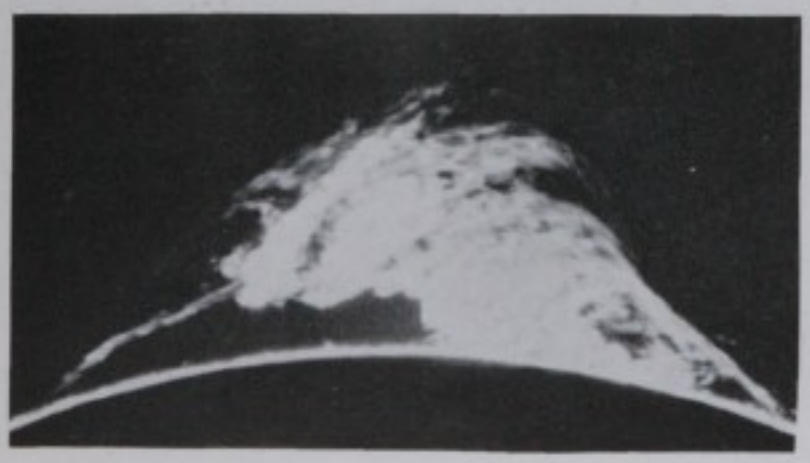
The survey program of the observatory, consisting of the daily coronal observations, flare patrol, limb patrol with the prominence telescope, and the recording of sunspots, is carried out by three observers employed by Harvard Observatory, under a research contract with the Air Force. Each day they develop films and plates, measure them, and record the information obtained from them. The next morning, the data are radioed to the High Altitude Observatory at Boulder, Colorado, where they are combined with similar observations from its Climax station. The results then go to the Central Radio Propagation Laboratory of the National Bureau of Standards, also at Boulder. There they are used in making up forecasts of radio propagation conditions, and in longer-range studies of correlations between solar and terrestrial events.

So far we have been looking at only the optical program, but Sacramento Peak Observatory also supports three important projects in solar radio astronomy. Unfortunately, such work cannot be carried out at the Peak, because of radio interference from the military activities at White Sands Proving Ground. Under a research contract with the Sacramento Peak Observatory, Harvard Observatory has now nearly completed the construction of a radio spectrum dynamic analyzer, which is to be located in a radio-quiet area in Texas, near McDonald Observatory. This instrument will scan the sun's radio emission from 100 to 600 megacycles, recording how solar radio noise varies in intensity at each frequency.

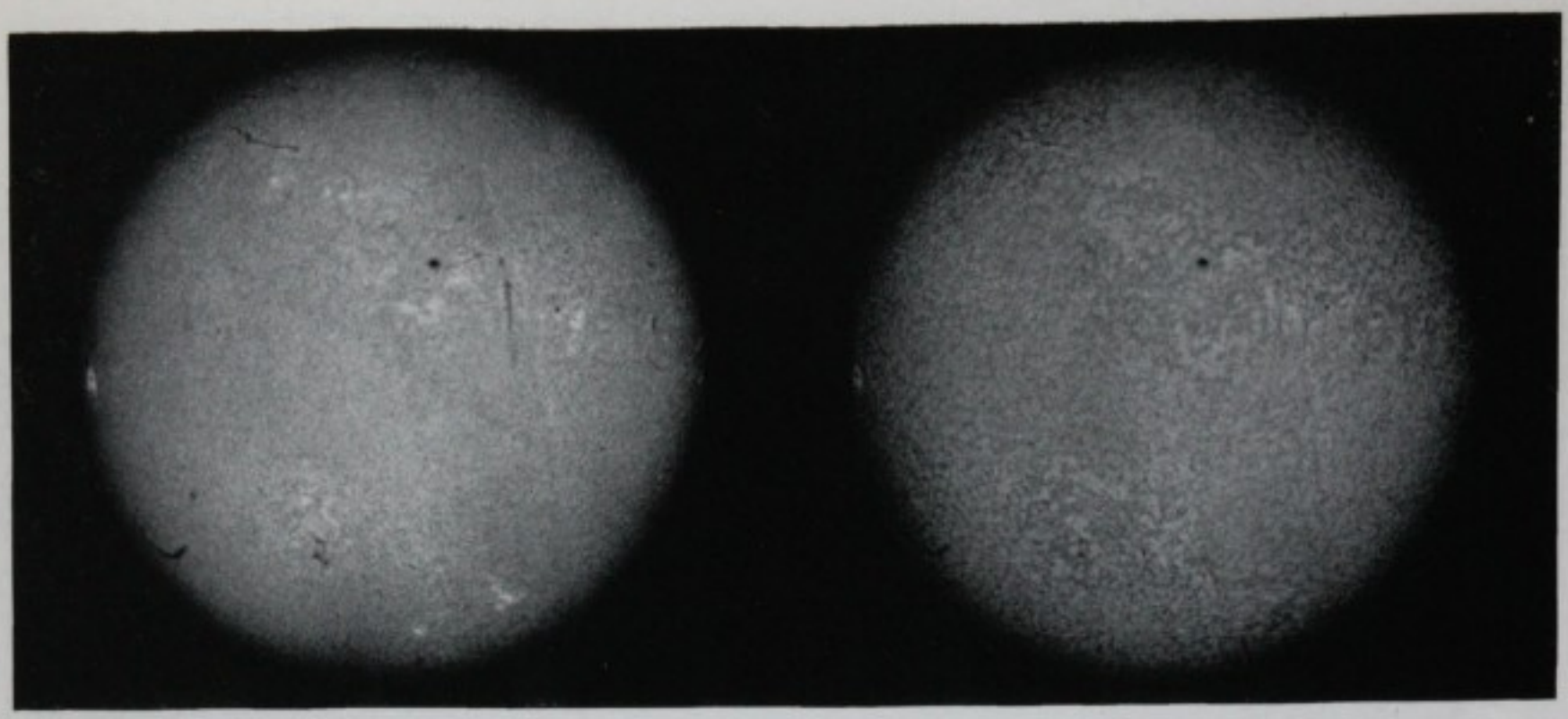
The second project, at Stanford University, uses a pencil-beam radio interferometer to locate the positions of emitting sources on the solar disk, and identify them with particular active regions. Comparing these radio records with simultaneous optical observations should help unravel the mysteries of the physical processes in active regions on the sun.

Our third radio research contract is with the Institute for Theoretical Physics, Oslo, Norway, where 200-megacycle radiation from the sun is monitored, at one station of an international network that keeps the sun under continuous 24-hour-a-day radio observation.

Although Sacramento Peak Observatory is one of the world's newest, its history is too complicated for more than a brief outline here. It was conceived by the present director of Harvard Observatory, Donald H. Menzel, and the project was



This large solar prominence was photographed in red light of hydrogen on August 3, 1955, with the 6-inch coronagraph mounted on the 10-foot spar.



Two photographs of the solar disk in H-alpha light, taken with the Sacramento Peak flare-patrol camera. In the left picture, the ½-angstrom filter was adjusted to pass light from the center of the H-alpha line; the other picture was made in light from the edge of this line, so features lower in the chromosphere could be observed. The black fleck above the center is a sunspot, and dark filaments are prominences seen in projection. The moderately bright patches are plages, useful indicators of disturbed regions. The very bright feature at the left edge of the sun is a flare.

started, with financial support from the Air Force, as a joint enterprise of Harvard, the High Altitude Observatory, and what has since become the Air Force Cambridge Research Center. The primary purpose of the observatory is a practical one: to study solar phenomena so disturbances in the earth's ionosphere can be predicted. It is these disturbances that cause radio fadeouts, geomagnetic storms, and aurorae. Since our program began, some definite effects of solar activity on terrestrial weather have been detected, and it may well be that weather forecasting will take the state of the sun into account in the future.

Work on Sacramento Peak began in August, 1947, when Rudy Cook and LeRoy Davis undertook a one-year test of the suitability of the site for coronal observations. Their work was carried out under great hardship in this isolated spot, but as time went on roads were improved, most of the observers married and brought their wives to Sacramento Peak, and prefabricated houses were erected to accommodate their growing families. When the 4-inch coronagraph was installed in mid-1949, more observers were added to the staff. The community continued to grow until permanent housing and laboratory facilities were built in 1952, and the 26-foot spar was set up. In September of that year, the writer was appointed superintendent, and the station became one of the eight laboratories now within the Geophysics Research Directorate.

In addition to our growth upon Sacramento Peak itself, solar research is being sponsored at other institutions by means of Air Force contracts. Mention has already been made of the projects in Texas, at Stanford, and at Oslo; others are at the High Altitude Observatory, at Lowell Observatory, and at the McMillin Observatory of Ohio State University. At these places supplementary programs of observation and analysis are carried out.

From its beginning, the Sacramento Peak station has shared its facilities with some visiting scientists having non-solar programs that require a very clear atmosphere. The present roster of projects includes:

—An atmospheric airglow observing station of the Geophysics Research Directorate, for mapping the intensity of emission lines over the entire night sky. The optical-radar atmospheric sounding station of the same organization, for measuring the density of the upper atmosphere by the amount of back scatter from a pulsed searchlight beam.

—A meteor observing station operated by Harvard Observatory for the Air Force, equipped with Baker super-Schmidt cameras and working in conjunction with a second station 22 miles away, at Mayhill, New Mexico. A meteor radar station of Stanford University, which co-operates with the super-Schmidt observers.

—Rocket tracking and telemetering groups from Holloman Air Development Center and White Sands Proving Ground.

After a long period of construction and preparation, Sacramento Peak Observatory now looks forward to making its contribution to solar physics and the explanation of solar-terrestrial relationships, by concentrating on observations for which our mountain location is particularly suited.

The 16-inch coronagraph turret is seen in a winter setting. All photographs with this article are courtesy of Sacramento Peak Observatory, Air Force Cambridge Research Center.

Mars on April 13, 1935, at 23:35 UT, by Sigemaro Kibe, with a 12-inch reflector and a magnification of 255x.

Japanese Observations of a Major Change on Mars

TSUNEO SAHEKI, *Osaka Planetarium*

ALL REGULAR OBSERVERS of Mars agree that the dark markings visible on this planet are only semipermanent. Their curious changes invite continuing study. Among the greatest of these alterations is the appearance of a new dark area northeast of Syrtis Major. This became widely known through the photographic observations in 1954 by E. C. Slipher, with the 27-inch refractor of the Lamont-Hussey Observatory in South Africa, and by E. Pettit and R. S. Richardson at Mount Wilson Observatory. According to their observations, this marking, centered at Martian longitude 255°, latitude 30° north, covered 1/50 of the planet's hemisphere—an area as large, relative to Mars, as Australia is to the earth. In *Sky and Telescope* for July, 1955, examples of the Slipher and Mount Wilson photographs were reproduced.

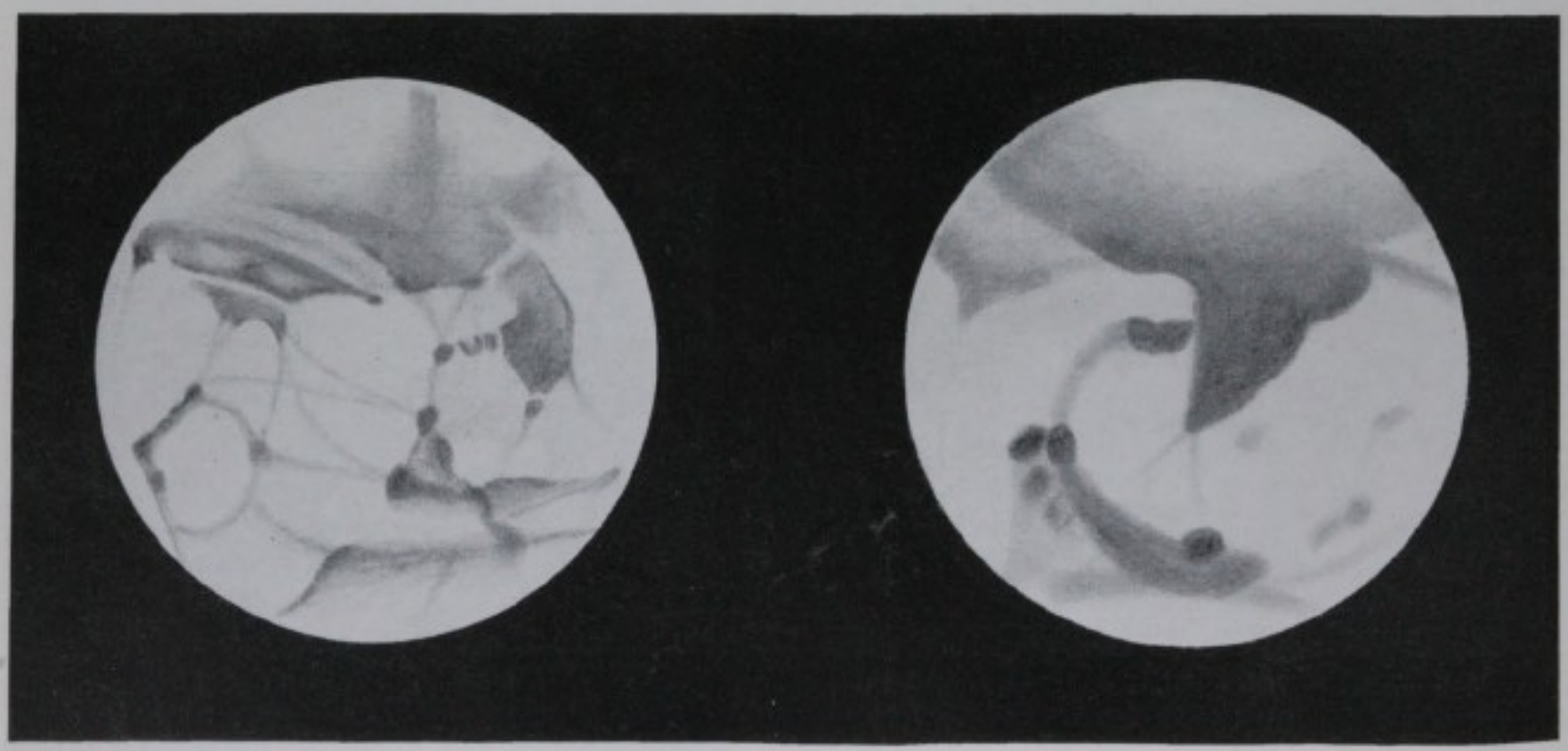
The confirmation of this new area was welcome to the members of the Mars section of the Oriental Astronomical Association, who have been watching the gradual development of the anomalous feature since 1937. The name *Nodus Laocoontis* has been proposed for it by Japanese observers, at the suggestion of Siro Ebizawa, of Tokyo, in 1953.

Our first record bearing on the origin of Nodus Laocoontis goes back to April 13, 1935. On that date S. S. Kibe, with a 12-inch reflector, saw a very faint and undefined shaded area northeast of Syrtis Major and east of Nodus Alcyonius, but this may have been a temporary phenomenon, as it was not seen again for many years. It appears in his drawing made at the time and reproduced here. This shows no canals except Thoth-Nepenthes, which does not quite touch Nodus Alcyonius. Just east (left) of the latter is the fainter, similar marking observed by Mr. Kibe.

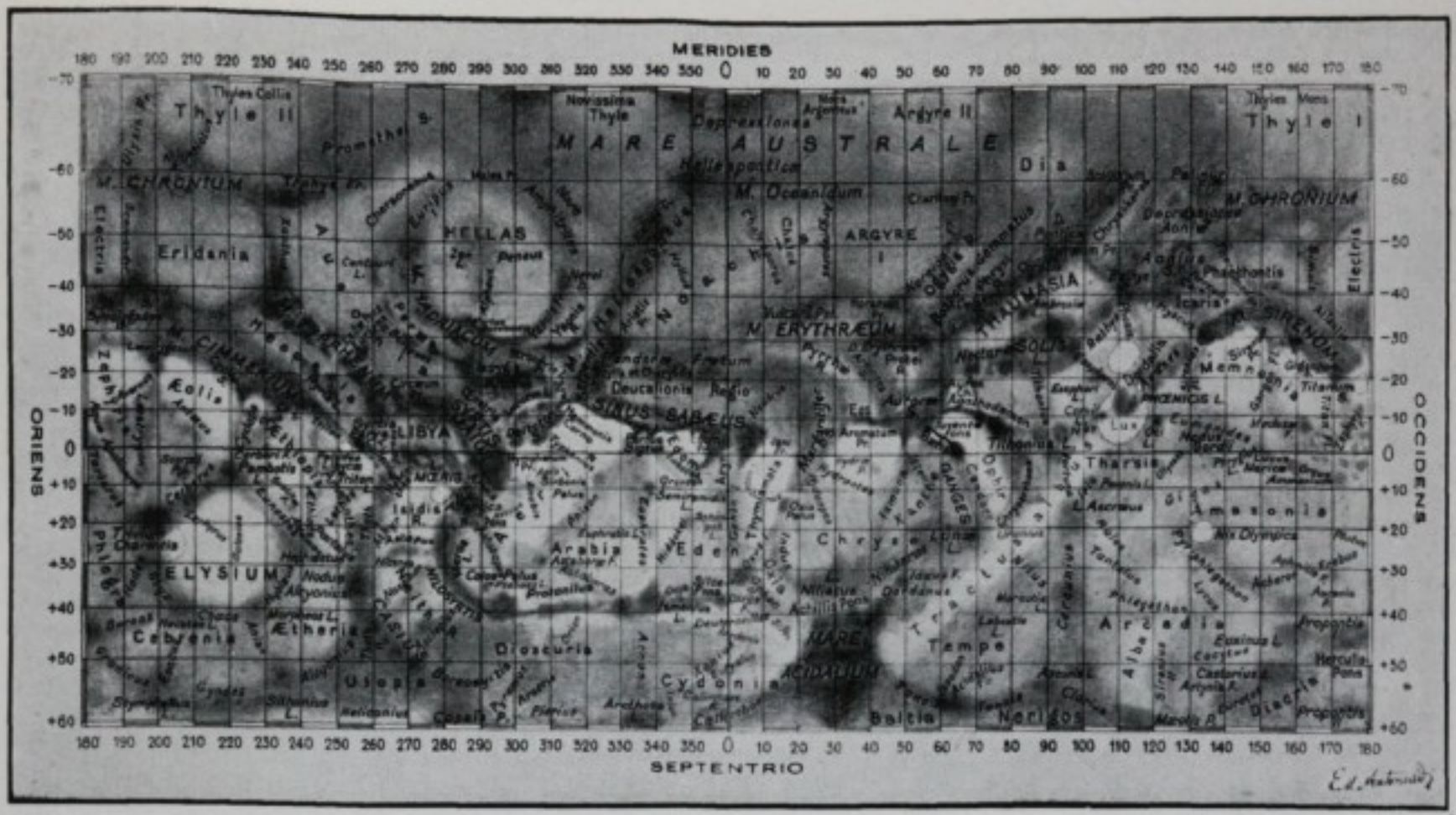
At the next opposition of Mars, in 1937, this Martian region was under watch because of the sudden development of Gomer Sinus, near the northwest end of Mare Cimmerium. On June 2, 1937, using the 11.8-inch refractor of the Kwasan Observatory at Kyoto University, I saw a remarkable development of the northwest part of Mare Cimmerium: a cigar-shaped marking in the south tropical zone of Mars, having the appearance of a sinus and extending northward to the equator, continuing as a conspicuous bandlike canal. This was confirmed the next night by Sizuo Maeda with an 8-inch reflector, and a few days later by Kibe.

The same feature was seen still further developed at the 1939 opposition by E. Date, S. Okabayasi, and by Kibe, with reflectors of 10, 12½, and 12 inches aperture, respectively. In the same year, Slipher photographed it in South Africa.

In the following oppositions of 1941, 1943, and 1946, we watched the continuing growth of Gomer Sinus into the northern hemisphere of Mars. Farther



The growth during nine years of the new dark area on Mars is seen by comparing these drawings by Tsuneo Saheki, and consulting the facing charts. The view at the left was obtained on June 2, 1937, at 20:00 UT, with powers of 420x and 900x on an 11.8-inch refractor. The other drawing shows nearly the same face of Mars, with all features shifted somewhat to the left, as seen January 9, 1946, at 1:40 UT, with an 18-inch reflector, 440x.



A map of Mars by E. M. Antoniadi, based on his work with the 33-inch Meudon refractor from 1909 to 1937.

north, the area up to Nodus Alcyonius was sometimes covered with a remarkable bandlike shadow. Finally, in the early morning of January 9, 1946, there reappeared Kibe's spot of 1935. This was detected by me with the 18-inch Calver reflector of the Yamamoto Observatory, and is shown here in my drawing of that date.

Soon afterward the dark band from Gomer Sinus reached the new spot, turning the whole area into a giant dark marking. The spot was still faint in 1946, and too difficult to be seen in 8-inch telescopes, but with larger aperture I thought that I could trace further development.

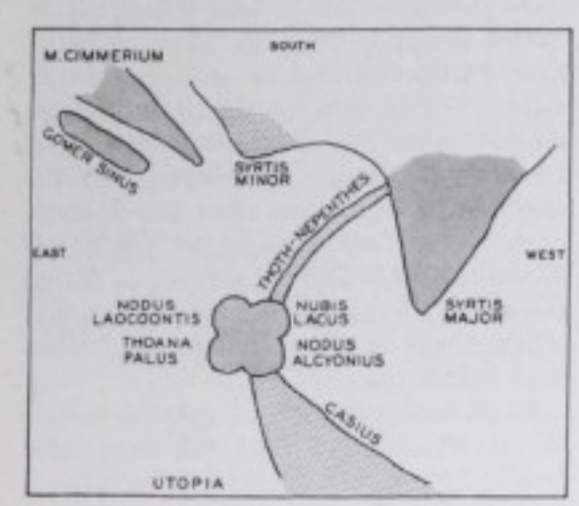
By 1948, however, the new spot and its dark surrounding area were much easier to see, and practically all the members of the Oriental Astronomical Association's observing section not only confirmed the existence of the spot but made detailed records of its dark nuclei.

During the 1950 and 1952 approaches of Mars, Nodus Laocoontis continued to grow and darken, and by the end of 1952 its two nuclei united. In that same year, Sadao Murayama, of the National Science Museum in Tokyo, succeeded in photographing the new phenomenon with an 8-inch refractor. The feature was seen by Ebizawa with his 13-inch reflector, in 1954, as resembling a devil's head with two horns.

Although it was very generally observed in 1954, our impression is that this Martian marking had reached its maximum size and intensity two years earlier. During 1954 it seemed to shrink, and its intensity weakened to that of Casius or Utopia. Perhaps it will continue to fade away in coming years, but this expectation cannot be tested definitely until 1960, for during the 1956 and 1958 oppositions the Martian northern hemisphere will be tipped away from the earth, hindering telescopic scrutiny of this region of the planet.

Although my account is confined to the Japanese observations, it should be mentioned that the new marking was independently detected in 1948 by W. H. Haas and others of the Association of Lunar and Planetary Observers, a group which has been co-operating closely with the Oriental Astronomical Association since 1950.

Mr. Saheki's manuscript was sent to *Sky and Telescope* through the courtesy of Dr. Issei Yamamoto, of the Yamamoto Observatory, near Ksatsu City, Japan.—ED.



Left: This schematic key chart of the active region on Mars will identify the features mentioned in Mr. Saheki's article.

Right: The Nodus Laocoontis dark complex has reached a striking stage of development in Sadao Murayama's drawing of April 27, 1950, 20:45 UT, with an 8-inch telescope, magnification 275x. Three large clouds are seen at the east and west edges of the planet, and the north polar cap is visible at the bottom.

NEWS NOTES

By Dorrit Hoffleit

ARTIFICIAL SATELLITE BIBLIOGRAPHY

The May issue of *Jet Propulsion*, journal of the American Rocket Society, is devoted primarily to problems of the artificial satellite, and includes "A History of the Artificial Satellite," by Alan R. Krull, of Northwestern University. This is primarily a bibliography of the important world literature on space satellites, including early fiction that contained useful speculations for later more serious developments.

Some 350 references are divided into periods: before 1900, at 10-year intervals up to 1950, and annually thereafter. There are some 60 author entries for the year 1955, compared with only a dozen for the 1920 decade. The three authors cited before 1900 are Edward Everett Hale, Kurd Lasswitz, and Jules Verne. In all cases, the general content of each article or book is indicated.

CHINESE OBSERVATIONS OF NOVAE AND SUPERNOVAE

The remnants of several old supernovae, such as Tycho's star of 1572 in Cassiopeia, have been recognized as strong sources of radio noise. To aid further identifications of radio sources with former supernovae, Hsi Tze-Tsung has made an extensive search in old Chinese chronicles for records of new stars. He has published in *Acta Astronomica Sinica, 3*, Part 2, 1955, a listing of 90 probable naked-eye novae and supernovae observed in China from 532 B.C. to A.D. 1690.

Of these 90 objects, he believes that 11 were supernovae, of which seven appeared in the last thousand years of this period. This would correspond to one supernova outburst per 150 years in our galaxy, on the average.

UNIDENTIFIED OBJECTS?

Extensive investigations by the U. S. Air Force of "flying saucer" reports have long indicated that all unidentified aerial objects could be explained on the basis of present knowledge if sufficient observational data were available. An analysis of official reports on the subject is published in the *Journal* of the British Interplanetary Society, March-April, 1956.

In recent years, as a result of on-the-spot investigations by the Air Intelligence Service, the proportion of unidentifiable cases has been steadily diminishing. The following tabulation represents the percentages in various categories of 854 reports during 1953 and 1954, and 131 reports for January 1 to May 5, 1955.

Category	*1953-54*	*1955*
Balloons	16%	26%
Aircraft	20	21
Astronomical	25	23
Other	13	20
Insufficient information	17	7
Unknown	9	3

ASTRONOMIA POPULAR

An attractive, well-illustrated new journal, *Astronomia Popular*, is being published in Mexico by the Mexican Center for Astronomical Research. The articles, in Spanish, include both original material and translations from foreign journals. It is international in scope, the first two issues containing contributions by G. Haro of Mexico, V. Ambarzumian of the U.S.S.R., and H. Dingle of England. The center, which has the establishment of a planetarium as one of its aims, invites prospective members and subscribers to write to Apartado Postal 7589, Mexico 1, D. F.

AMERICAN ASTRONOMICAL SOCIETY MEETING

On August 24-28, the American Astronomical Society and the Astronomical Society of the Pacific will hold a joint meeting at Berkeley, Calif. The sessions for papers are to be in Dwinelle Hall of the University of California. This year's Russell lecture will be given by Dr. Joel Stebbins. The program also features a symposium on evolution in the galaxy, and an excursion to Lick Observatory.

PALLAS AND M15

An unusual telescopic sight may be enjoyed by amateur observers on August 8-9, as the minor planet Pallas passes in front of the bright globular cluster Messier 15 in the constellation Pegasus. The position of this cluster is $21^h\ 27^m.6$, $+11°\ 57'$ (1950 co-ordinates), and its diameter is variously cited as 7.4 and 12 minutes of arc. Since Pallas is moving $8\frac{1}{2}'$ per day southwesterly, and will cross the cluster nearly centrally, it will spend about one day in transit. The least distance of the asteroid from the center of the cluster will occur in the morning hours of August 9th for observers in the Americas.

Pallas will be about magnitude 9.2, hence much brighter than member stars of M15, but faint enough so that confusion with field stars is possible. To facilitate prior identification of Pallas, the following ephemeris covers dates preceding the transit; it gives 1950 right ascensions and declinations for 0^h UT, which corresponds to 7 p.m. EST on the previous date.

August	7	21^h	29^m	19″	+12°	17′.2
	8	21	28	33	+12	09.2
	9	21	27	47	+12	01.1
	10	21	27	01	+11	52.7

A series of photographs taken with an instrument having a large plate scale would make an interesting record of the path of Pallas relative to M15.

VENUS AS A RADIO SOURCE

(Continued from page 435)

from Venus observed by John D. Kraus at Ohio State University are of another nature. In February, 1956, he began a search for radio emission from Venus, using a small interferometer-type radio telescope operating at 11 meters wave length. Its antenna consists of two arrays 400 feet apart, each containing six horizontal elements backed by a reflector. The apparatus is set up on Dr. Kraus' farm northwest of Columbus, Ohio.

Once in February and several times in March records were obtained which seemed to indicate reception of noise from Venus, but not until May were sufficiently detailed observations obtained to make it certain that this planet was indeed the source.

As shown by the sample record reproduced on page 435, the 11-meter static from Venus consists of numerous brief bursts, lasting one second or less, which appear on the records as sharp spikes. Because of the lag of the recording pen, signals lasting much less than one quarter of a second would not be registered. When the output of the receiver is played through a loudspeaker, a crackling sound is heard, not unlike the static from terrestrial thunderstorms.

Dr. Kraus finds indications of periodicities in Venus static that may eventually reveal the rotation period of that planet.

IN THE CURRENT JOURNALS

THE BIG DIPPER, by C. H. Cleminshaw, *Griffith Observer*, April, 1956. "For nearly a century it has been known that five of the seven stars in the Big Dipper have a common apparent motion across the sky, moving together like a flock of birds."

INFRARED RADIOMETRY, *Techniques*, Barnes Engineering Co., 30 Commerce Rd., Stamford, Conn., Spring, 1956. "Remote temperature measurement by means of infrared radiometry is possible because the radiation emitted by a body is a well known function of its temperature. A radiometer, in the modern sense of the term, is an optical instrument which collects radiation from a narrow field of view and converts the received energy into an electrical signal."

MY TILT WITH ALBERT EINSTEIN, by Carlos Graef Fernandez, *American Scientist*, April, 1956. "'Yes. An explanation for us is nothing but an order of formulae which empowers one to predict the future.'

"Einstein vehemently disagreed. 'The set of formulae, which for you is all there is to an explanation, has to be consistent with the philosophy of nature in order to be a true explanation. Otherwise it is only a convenient device for predicting the future of a system, but does not give a real insight into its nature.'"

A Complex Perseid Meteor Spectrum

PETER M. MILLMAN, *National Research Council of Canada,*
formerly at the Dominion Observatory, Ottawa

DURING observations of the Perseid meteor shower in August, 1952, the spectrum on the third page of this article was photographed by the writer at Meanook Meteor Observatory, Alberta, with the assistance of G. A. Brealey. This is a station operated by the Dominion Observatory, Ottawa, and is located in latitude 54° 36′ 56″ north, longitude 113° 20′ 45″ west, at 2,240 feet above sea level. At the same time, A. A. Griffin and J. M. Grant were taking direct photographs of the Perseids at the Newbrook Meteor Observatory 25.6 miles distant, at latitude 54° 19′ 26″ north, longitude 112° 57′ 15″ west, elevation 2,200 feet.

The meteor appeared in Cygnus at 0:52:44 MST, August 13, 1952. Its visual magnitude was estimated as −2 by Mr. Griffin at Newbrook. I was walking down to the power house in Meanook at the time to check the frequency control of the generators and did not see the meteor itself. The flash, however, was bright enough to be seen on the ground, and when I looked up the train was clearly evident, remaining visible to the naked eye for between 10 and 12 seconds. From the appearance of the Meanook spectrum photograph, the Newbrook estimate of visual magnitude may have been a bit faint. The distance of the meteor from Newbrook (where sky conditions were poor, with considerable cloud) was only 5 to 10 per cent greater than from Meanook (where the sky was clear). Thus it is quite possible that the meteor was brighter than magnitude −4 at maximum light, as seen from the spectrum-camera site.

The picture was taken with a Williamson aerial camera, equipped with a Pentac lens of 2.75 inches aperture and of 8-inch focus. This camera was one of three on the same mounting, which was designed by the Radio and Electrical Engineering Division of the National Research Council, Ottawa.[1] A similar mounting, in use near Ottawa, is illustrated here. At Meanook, a four-vane rotating shutter covered the lens 24 times per second, giving equal intervals of exposure and occultation, thus chopping a meteor trail into segments, whose lengths indicate the meteor's velocity.

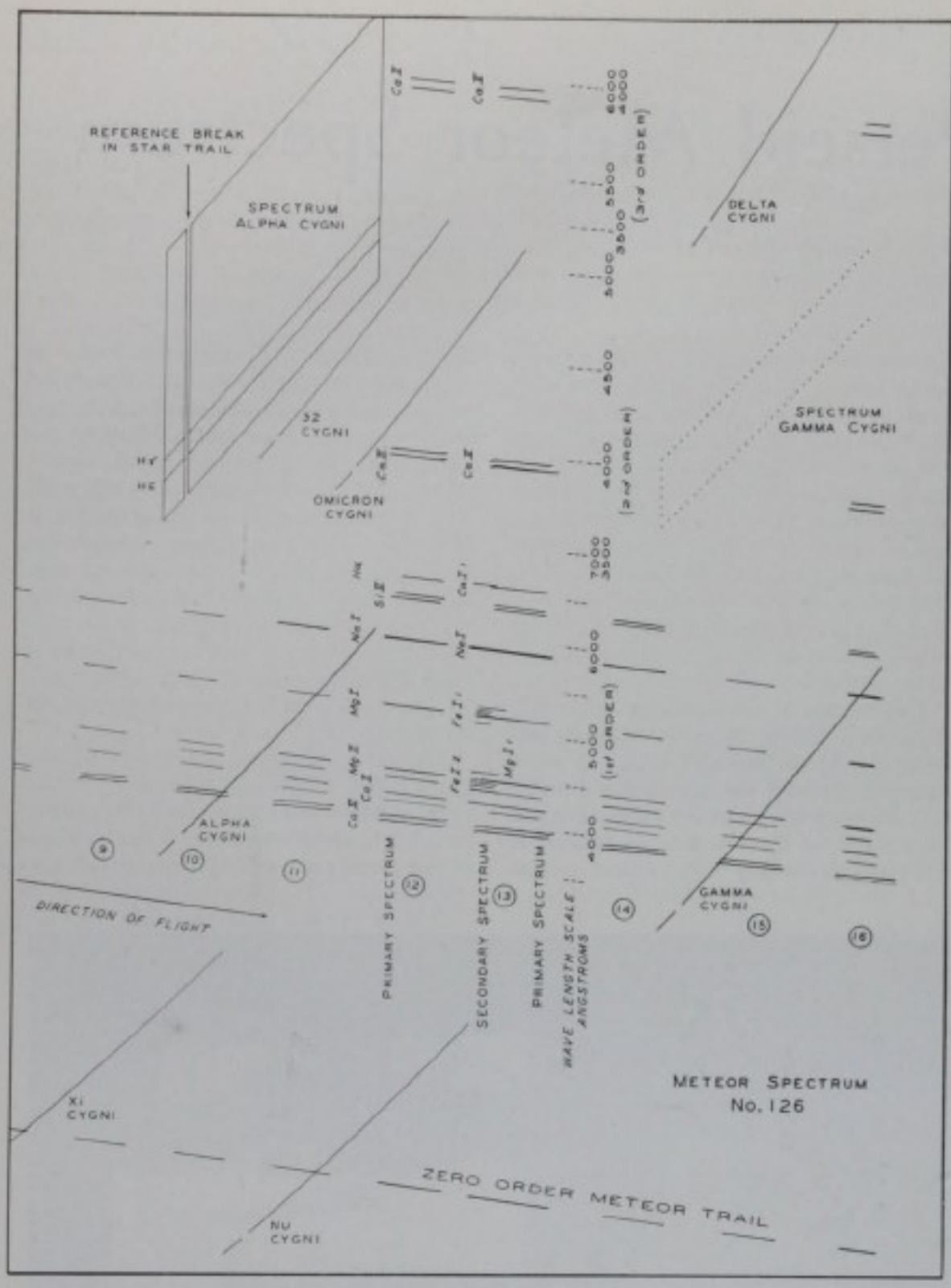
To form the spectrum, in front of the lens was placed a Bausch and Lomb replica grating, mounted on glass and ruled with 200 lines per millimeter. It must be remembered that a grating, in contrast to a prism, gives a direct image and a number of spectrum images on both sides of this. In old-fashioned gratings the percentage of light in any one image was small. Modern techniques of cutting the grating grooves now make it possible to concentrate most of the light into one specific spectrum image. Thus, at Meanook we used such a blazed grating, which directed about three quarters of the incident light into the first-order spectrum above the direct image as the picture is here oriented.

The emulsion was Eastman Super XX Aero film, which comes in rolls 56 feet long and 5½ inches wide. This is sensitive to light from the ultraviolet through the visible spectrum to a wave length just to the red of the H_α line of hydrogen.

The exposure was for 22 minutes, from 0:40 to 1:02 MST, and the lens was covered for 20 seconds at 0:42. The direct images of the star trails can be seen running diagonally from lower left to upper right, with the 20-second break clearly visible near the beginning of each trail. The brightest star in the photograph is Deneb, a white supergiant star of apparent magnitude 1.3. Its spectrum can be seen above its direct trail, and on the original exhibits strongly the very narrow dark lines of hydrogen typical of these high-luminosity *A* stars. Other stellar spectra appear very faintly against the sky background.

The direct image of the meteor on the original film showed 16 segments, the last eight of which are reproduced; the meteor traveled from left to right. Two maxima of light occurred, one at segment 13, the

Peter M. Millman and a battery of meteor spectrographs similar to the one with which the Perseid spectrum on page 447 was obtained. Photograph by George Hunter for the Dominion Observatory.



This chart provides a key to the photograph of the Perseid meteor spectrum opposite, which was made with a diffraction grating. It shows at the bottom a direct image of the meteor itself in the zero order, broken into segments by a rotating shutter. But the turning of the shutter was too rapid to affect the star trails, which appear in the zero order also. Next upward in the picture is the spectrum of the first order, with the violet H and K lines of ionized calcium prominent, together with lines of many other elements. Then come spectra of the second and third orders, but these are relatively weak and show practically only the H and K lines. The first-order spectrum of Deneb contains typical hydrogen absorption lines. A portion of the meteor fragmented off between segments 12 and 13, producing the secondary spectrum of lower excitation. From the original negative of this picture all of the lines in the table on page 448 have been identified. Dominion Observatory photograph.

other at the end of the trail, segment 16. The first of these segments is compound, for it shows a secondary image trailing behind the primary. This secondary image resulted from a portion broken off from the main meteor mass, giving a spectrum of much lower excitation and hence very different from the primary spectrum.

A direct photograph of the same Perseid was secured at Newbrook, where the height of appearance was 112 kilometers, according to a preliminary reduction of the two photographs. Segment 1 on the Meanook plate corresponds to a height of 107 kilometers. The heights of the last 11 segments of the spectrum photograph are: Segment 6, 97.8 kilometers; 7, 95.8; 8, 93.9; 9, 91.9; 10, 90.0; 11, 88.1; 12, 86.2; (secondary, 85.0) 13, 84.3; 14, 82.4; 15, 80.5; 16, 79.0.

The visual persistent train that I plotted at Meanook was found to occupy a position from segment 6 to segment 13, corresponding to heights from 98 to 84 kilometers. The lower end of the visual train apparently coincided with the first light maximum of the primary mass, and with the maximum light of the secondary, which was trailing the main mass by about 1.5 kilometers at this point. (The height of the secondary spectrum here is nearly the same as that of the brightest part of the train spectrum of a 1949 Perseid recorded at Ottawa.[2])

The apparent radiant point of this meteor was at altitude 48°, azimuth 51° east of north, very close to the average position of the Perseid radiant for the date. A preliminary calculation of the observed velocity gives just over 60 kilometers per second, again in close agreement with the mean for the Perseid shower.

It will be noticed that the images of the ionized calcium lines are twisted at the ends, making them resemble integration symbols. This peculiar appearance results from lens aberrations, which are stronger at the violet end of the spectrum. The resulting slightly out-of-focus image is shifted when part of the lens is covered by the shutter, as is the case at either end of a segment of the trail.

This meteor spectrum is No. 126 on the world list.[3] More than 100 lines were measured in the primary spectrum and over 30 in the secondary. The features of the primary agree well with those of typical Perseids,[4] but they are shown here in greater detail than in any other meteor spectrum yet photographed. Thus Table I, in which are given the wave lengths of the lines measured, serves as a convenient guide to lines normally present in the spectra of fast meteors. The strongest lines are marked with asterisks. The reader should be able to pick out most of the lines with the help of the wave-length scales given in the key to the photograph. In general, the observed meteor wave lengths agree very well with those predicted from blends of laboratory wave lengths.

An atom of any element may exist in one of a number of states, each characterized by a definite amount of potential energy of the atom. When an atom changes from a higher energy level to a lower, light may be emitted, and this light has a wave length inversely proportional to the energy lost by the atom. If the energy levels in an atom are themselves complex, one pair of levels may have several possible energy differences, and give rise to several wave lengths, or spectral lines. These are said to form a multiplet, and a single multiplet may contain many lines. In discussing spectrum photographs such as this one, it is convenient to consider the multiplets as units, since the lines of one multiplet generally appear or disappear together. Therefore Table I also shows the multiplets identified for each element, num-

TABLE I — WAVE LENGTHS MEASURED IN SPECTRUM NO. 126

Primary Spectrum I.A.	*Multiplets Identified*	*Secondary Spectrum I.A.*
		FeI 23 3612
3706.9	FeI 5 FeI 21	
3740.7		
3766.1		
3813.9	FeI 4 FeI 20 MgI 3	
3833.4		
3843.5		
3859.6	SiII 1	
3868.2		
3886.8		
3933.5*	CaII 1	SiI 3 3927.5
3968.7*	FeI 43	3963.7
4005.3		
4031.0	MnI 2	
4045.2		4045.0
4063.4		4063.7
4071.3		
4105.3		SiI 2
4116.4	FeII 28	
4129.9	FeI 3 FeII 27	SiII 3
4143.0		
4177.5	FeI 42	
4188.5	FeI 152	
4201.1		
4211.2		4214.7
4226.5*		CaI 2 4225.2*
4235.4		
4249.1		
4254.8		4254.8
4261.8		
4272.4		4270.0
4291.0		FeI 41 4290.7
4307.7		4307.7
4325.6		4324.8
4338.5		
4352.8	MgI 14	
4376.5		4375.0*
4383.3*		
4394.2		
4404.9		4403.4
4415.6		
4427.8	FeI 2	CaI 4 4426.2*
4433.9		
4462.0	FeII 37	4460.9*
4481.4*	MgII 4	4482.5*
4508.1	FeII 38	
4516.6		
4523.1		
4531.0		
4546.0		
4552.6		
4556.9		
4570.2	MgI 1	CaI 23 4569.4
4584.7		
4616.9		
4630.1		
4647.4		
4666.4		
4700.7	MgI 11	
4863.1	FeI 318	HI 1
4873.9		
4888.8		
4923.0	FeII 42 FeI 16	
4957.6		
5012.8		
5018.4		
5024.4		
5040.2		SiII 5
5056.8	FeI 1	
5110.2		5108.8*
5126.6		
5143.8		
5170.3*	MgI 2	5167.9*
5184.0*		5180.9
5186.2	FeII 49 CaI 49	
5206.1		5206.4
5229.8		5225.6
5249.2		5248.6
5269.1	FeI 15 FeII 48	CaI 227 5271.6
5301.8		
5313.7		
5326.0		5327.8
5369.4		
5403.4		
5429.4		5432.6
5433.2		5454.1
		5484.3
		MgI 9 5531.4
5559.9	NI 25?	
5591.3	CaI 21	
5603.9		
5635.9	FeI 1087?	
5659.6		
5683.4	NaI 6	
5861.3	CaI 47	
5870.7		
5892.4*	NaI 1	5891.0*
5948.0	SiI 6	
5979.4	SiII 4	
6008.3	NI 16?	
6124.5	CaI 3	
6159.4	FeII 74? CaI 20 NaI 5	6163.3
6316.9	FeI 13? FeI 168 MgI 23	
6347.3*	SiII 2	
6371.2*		
6399.1		
6438.9	CaI 18	
6448.6	CaI 19	
6459.3		
6465.6		
6478.5		
6486.4		
6494.2		
6505.6		
6562.9	FeI 268 HI 1	
	CaI 1	6573.0
		6594.6
6620.3	NI 20?	
6657.7		
6695.7	AlI 5?	

bered as in the tables by Charlotte E. Moore, in *Contributions from Princeton Observatory*, No. 20, 1945.

The secondary spectrum, produced by the material that broke off from the main mass, has a marked absence of all the ionized lines but those of CaII (singly ionized calcium), which appear at greatly reduced strength. On the other hand, multiplets arising from the ground levels of the neutral atoms are unusually strong, notably FeI 1, FeI 2, MgI 1, and CaI 1. Generally the spectra of fast meteors show the ionized lines of magnesium, silicon, iron, and calcium, but this secondary spectrum confirms evidence from other meteor spectra that the light from the small particles or dust trailing behind a fast meteor may be of relatively low excitation. Bursts in meteor trains seem to result from rapid disintegration of a portion of the main mass, which increases the number of trailing dust particles; thus it is not surprising that the excitation of the iron vapor tends to be lower at bursts, as was found by the writer in 1935.[5]

In all, 66 multiplets of nine neutral elements (FeI, MnI, CaI, SiI, AlI, MgI, NaI, NI, and HI) and of four ionized elements (FeII, CaII, SiII, and MgII) have been identified in the spectrum of this meteor. The photometric study of this photograph has not been completed.

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2. Millman, P. M., *Nature*, *165*, 1013, 1950.
3. Millman, P. M., *Journal* of the Royal Astronomical Society of Canada, *47*, 217, 1953.
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5. Millman, P. M., *Annals* of Harvard College Observatory, *82*, 149, 1935.

OTTO STRUVE'S ACCIDENT

The well-known California astronomer, Otto Struve, a regular contributor to this magazine, suffered serious injuries while observing with the 60-inch reflector at Mount Wilson Observatory on May 22nd. At 8:30 p.m., he and the night assistant were lowering the apron under the shutter, in order to observe some low southern stars, when Dr. Struve fell from the narrow platform 10 feet to the floor below. He was unconscious for 10 minutes.

At the hospital in Pasadena, he was found to have cracked several ribs, a shoulder blade, and two vertebrae. On May 31st, he was taken by ambulance to the Herrick Hospital in Berkeley, where a five-week stay in bed was indicated, but Dr. Struve had hopes of being back at his desk in Leuschner Observatory by July 1st.

This accident, as well as the similar mishap to A. H. Joy at the 100-inch telescope in 1946, points to the problem of the observer's safety in large telescope installations. That astronomy is a fairly hazardous occupation is suggested by other instances in Dr. Struve's own family.

His father, Ludwig Struve, was director of the observatory at Kharkov, Russia, half a century ago. Twice he broke his leg while observing with the meridian circle, both times from the carelessness of an assistant, who left open a trapdoor leading to the clock room in the cellar.

Otto Struve's great-grandfather was Wilhelm Struve, director at Dorpat and later at Poulkovo. He used to say that the famous 9.4-inch Dorpat telescope was rightly called "the great refractor" because he and his friend Schumacher had each broken a leg while observing with it.

Element Formation in Stars—II

OTTO STRUVE, *Leuschner Observatory, University of California*

IN the first part of this article, last month, we discussed how Fowler and Greenstein succeeded in explaining the formation of many heavy elements in the interiors of stars that originally contained only hydrogen. Their explanation involves nuclear processes starting, at about five million degrees, with the proton-proton cycle which formed helium out of hydrogen. At higher temperatures, about 150 million degrees, alpha particles (helium nuclei) combined to produce Be^8 (beryllium nuclei of mass 8), which in turn could capture alpha particles and make C^{12}. Then, by means of further alpha-particle captures, O^{16} and Ne^{20} were produced. Finally, at about five billion degrees, still heavier nuclei, including Fe^{56}, were created.

Fowler and Greenstein assume that these first-generation stars then expelled much of their material into the interstellar medium, from which second-generation stars were formed, containing not only hydrogen but carbon, oxygen, and neon. We can ask, however, if this assumption is necessary, for would not the C^{12} formed in the first-generation stars allow element building by the carbon-nitrogen cycle (described on page 393 last month)?

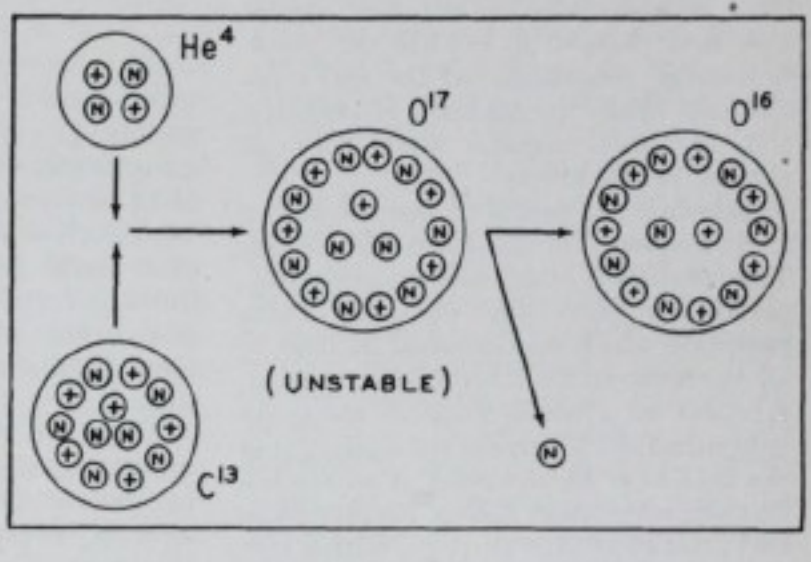
The difficulty with this alternative is that C^{12} first appears at the very high temperatures of over 100 million degrees that occur only in stars largely exhausted of their original hydrogen supply. Hence, even if the carbon-nitrogen cycle should operate, it would do so very rapidly, quickly consuming the few remaining protons; this cycle could not provide the luminous energy of first-generation stars for any great length of time. But this does not mean that the carbon-nitrogen cycle does not exist at all in such stars. It could produce additional nuclei in a still relatively cool outer layer containing abundant hydrogen, if carbon nuclei could migrate into the layer from a very hot stellar core.

Hence, the Bethe-von Weizsäcker reaction takes place, perhaps, in such cooler outer layers of first-generation stars, as well as in second-generation stars that are cooler inside (upward of 15 million degrees) and have a large supply of hydrogen from the original gas with a small admixture of carbon.

As we stated last month, the carbon-nitrogen cycle produces new isotopes: N^{13}, C^{13}, N^{14}, O^{15}, and N^{15}. There is a parallel series of reactions whereby ordinary oxygen is converted by proton capture into an isotope of fluorine (F^{17}), which decays by positron emission to O^{17}. Then this heavy isotope of oxygen, upon colliding with another proton, splits into ordinary nitrogen (N^{14}) and an alpha particle. In a somewhat similar manner, the heavy isotope of neon (Ne^{21}), is also produced.

These heavy isotopes of carbon, oxygen, and neon differ from their lighter counterparts because they each contain an extra neutron, just as the deuteron differs from the proton by its extra neutron. Such neutron-rich isotopes are especially important, because they can capture alpha particles and expel the extra neutron. Thus, at 85 million degrees, in these second-generation stars, there are such reactions as the capture of an alpha particle by C^{13}, yielding O^{16} and a neutron. Similar reactions convert O^{17} to Ne^{20}, and Ne^{21} to Mg^{24}. These processes furnish a large supply of free neutrons.

Because they have no electric charge, neutrons are not repelled by the positively charged atomic nuclei. Hence, they are easily captured and thus produce, step by step, still heavier elements up to lead (Pb^{208}), or bismuth (Bi^{209}). For example, the light isotope (Au^{197}) of gold can acquire a neutron to become Au^{198}, with the release of gamma radiation. If this nucleus should next emit an electron, with one negative charge, it would form a particle of the same mass number, 198, but having 80 positive charges. This would be the fairly abundant isotope of mercury, Hg^{198}.



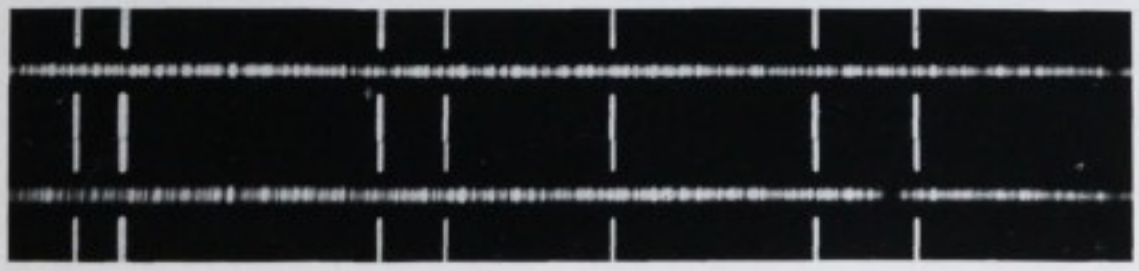
Two products of the carbon-nitrogen cycle, helium and the heavy isotope of carbon, can unite to form heavy oxygen, whose decay releases a neutron. Such reactions supply neutrons to permit building of heavy elements.

Each free neutron, however, is radioactive: In about half an hour it spontaneously ejects a negative electron and transforms itself into a proton. Hence, for efficient building of heavy elements in the stars, there must be a continuing supply of large numbers of free neutrons.

The laboratory discovery of the neutron was made by bombarding a beryllium target with alpha particles. The target ejected penetrating particles, carrying no electric charge, but with masses nearly equal to those of protons. The beryllium had been converted into ordinary carbon and neutrons. But in the stars Be^9 is so rare that this reaction could not produce a sufficient supply of free neutrons.

The explosion of an atomic bomb releases numerous free neutrons, which during their short lifetimes build up elements heavier than uranium. These processes are similar to those occurring in stars of the second generation.

But the Fowler-Greenstein theory, as it now stands, does not explain the large abundances of the third lightest element,



The upper spectrum is of UU Aurigae, an N3-type star with weak lithium lines. Below, in WZ Cassiopeiae, the lithium line at 6707 angstroms is very prominent, one inch from the right end. The bright lines are from a laboratory neon source. Dominion Astrophysical Observatory photograph.

lithium, in several late-type stars. Nor does it account for the presence of technetium, element number 43, only recently identified in such stars. Lithium is not synthesized in stellar interiors, but instead is destroyed by proton bombardment at temperatures of the order of only 200,000°; each lithium-proton combination becomes two alpha particles. Technetium is radioactive, and decays into lighter elements within a few hundred thousand years. Possibly the technetium in the atmospheres of red giants has been built up in their interiors, and is brought to the surface of each star by strong convection currents; but if so the mixing time must be less than half a million years.

To explain the presence of lithium, which Greenstein and R. S. Richardson have definitely identified even on the surface of the sun, Fowler and the Burbidges have worked out the betatron effect of the magnetic spots that occur on the surfaces of many stars. They also suggest such a mechanism to explain the peculiarly large abundances of the rare-earth elements in the atmospheres of magnetic and spectrum variable stars (like α^2 Canum Venaticorum).

Although the details of this theory are fairly involved, the basic ideas are simple. The betatron is a high-energy accelerator, principally used for electrons (beta particles), which was invented in 1940 by D. W. Kerst at the University of Illinois. It works on a modification of the cyclotron principle. Electrons are injected into the field between the poles of an electromagnet, where they follow circular paths and form an electric current. With a constant magnetic field, the electrons have constant velocities, but if the field strength is increasing, the electrons are accelerated. To prevent them from spiraling outward, the magnetic flux density also grows and they continue moving in a circle with ever-increasing speed and energy. Several hundred thousand revolutions may be made, and betatron energies can reach 100 million electron volts.

An energy of one electron volt corresponds to a velocity of each electron of 600 kilometers per second. With this energy a proton, roughly 2,000 times as heavy as an electron, would travel at a rate of only 14 kilometers per second. In the largest existing accelerators, such as the Berkeley bevatron (name derived from billion electron volts), the particles may be accelerated to about six billion electron volts. They then travel with velocities approaching that of light.

On the surface of a star with a temperature of 10,000°, the velocities of protons are of the order of 10 kilometers per second. This is the equivalent of about one electron volt—far below the energy required to produce any nuclear transformations. But the sun has spots which form in the course of only a few hours from the quiescent solar photosphere. Strong magnetic fields are generated in these disturbed areas and, while the fields are increasing, large accelerations will be experienced by nearby charged particles, both ions and electrons.

Fowler and the Burbidges have suggested that in some stars even stronger magnetic spots, of the order of one million gauss (which is 100 times stronger than has been observed in the sun), are built up in a few hours. This could give many particles betatron-type accelerations of 10 or even 100 million electron volts. With such enormous energies, the particles could indeed synthesize not only lithium, beryllium, and boron, but the rare earths and other heavy elements found to be abnormally abundant in some stars.

D. W. Kerst and his original betatron, invented in 1940. By this modification of the cyclotron principle, a compact device is obtained for accelerating electrons to velocities nearly that of light. University of Illinois photograph.

These are stimulating ideas, but the theory of nuclear processes in stars would be sterile if it were not possible to verify some of its predictions by means of observations. The following important part of our discussion is due mainly to Greenstein. The illustrations of stellar spectra have been kindly provided by Guido Münch, Mount Wilson and Palomar Observatories, and by Andrew McKellar, Dominion Astrophysical Observatory.

First of all, is there any evidence that the original medium out of which the earliest stars of our galaxy were formed consisted of hydrogen only? There are now no stars known that are pure hydrogen, but this is not unexpected, for even the oldest first-generation stars (which may have been once entirely hydrogen) have had some six billion (6×10^9) years to convert much of their hydrogen into heavier elements. Their atmospheres should contain some admixture of heavy elements, brought up from their interiors by even very slow mixing, in the form of convection currents.

Nevertheless, one of the most remarkable results of spectroscopic studies of very old stars—the high-velocity stars and those in certain globular clusters—is that their atmospheres are relatively deficient in metals. Their spectra show hydrogen lines of normal intensity for their relatively low surface temperatures of about 4,500° (spectral class *K*), but their metallic lines are so faint that the observer is tempted to assign a spectral class of *F*. In the most abnormal members of the high-velocity group, the deficiency of the metals may reach a factor of 20. As Greenstein puts it: "Such stars can be relics of the earliest days of element and star formation," when the diffuse medium of the galaxy was mainly hydrogen.

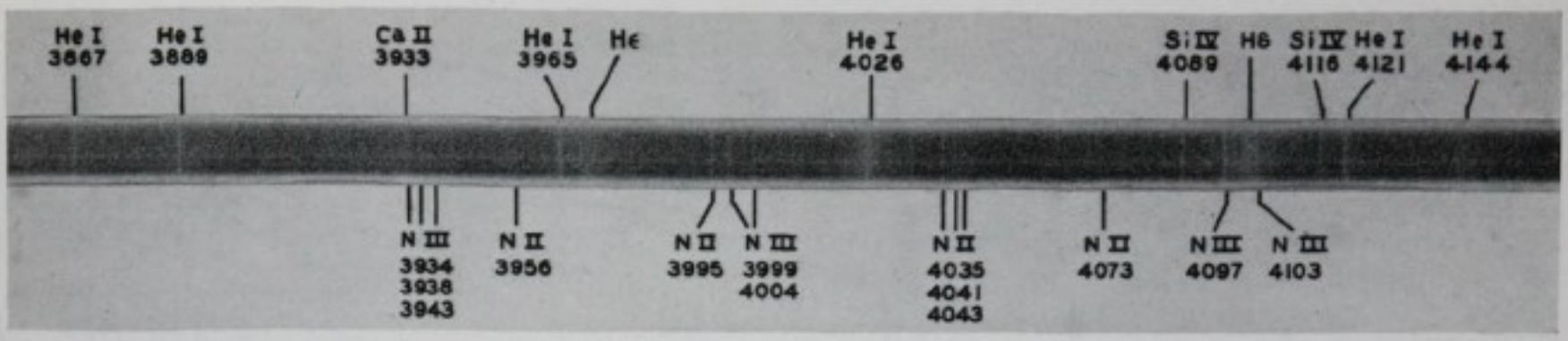
It is useful to distinguish between the absolute age of a star in years and its evolutionary stage. The latter may be defined as the fraction:

$$\frac{\text{Age of the star in years}}{\text{Total life span of star}}$$

The total life span of a star of the sun's mass may be 5×10^{10} years or even longer, if by life span we mean the interval between the formation of the star and its ultimate conversion into a white dwarf. Hence, even though the sun is old in years, probably 4.6×10^9, its evolutionary stage is only of the order of 1/10. The high-velocity stars and the cool giants in globular clusters are older in years, perhaps 6×10^9, and their average life span may be somewhat shorter than the sun's, say 2×10^{10} years. Their evolutionary stages should be about 1/3. They have not completely exhausted their hydrogen supply; at least at their surfaces there is still more hydrogen in relation to heavy elements than in stars of recent origin.

What about stars whose evolutionary stages are close to 1/1? The best objects to examine would be relatively massive stars, which expend their energy rapidly and have short life spans. Even though of considerable age, these stars could still be much younger than the sun, and they may even be second-generation stars born from a medium enriched in heavy elements. Such stars, most likely to be found in the upper regions of the spectrum-luminosity diagram, should not be numerous, for their evolution has taken place much more rapidly than if they were on the main sequence and still had a large supply of hydrogen fuel.

Greenstein, Münch, and others have found a number of such objects, usually described as underluminous blue stars. Some were first discovered by F. Zwicky and M. Humason long before anything was known about their evolutionary



Strong helium and weak hydrogen lines indicate an advanced evolutionary stage for the star HZ 44, whose spectrum is shown here. Dr. Munch states that he knows five other similar stars, and that they seem quite different from objects in the blue branch of the H-R diagrams of globular clusters. Mount Wilson and Palomar Observatories photograph.

status. As a reasonable guess, we may now assign to them an evolutionary stage of about 0.8 or 0.9. They have substantially exhausted their hydrogen, and they are old enough in years to have experienced a considerable amount of mixing. Even their atmospheres are depleted in hydrogen and rich in helium. The spectrum of one such star, No. 44 in the Humason-Zwicky list, is shown here; the line of neutral helium at 4026 angstroms is, for instance, very strong, and there are many other prominent lines of helium. On the other hand, the hydrogen-epsilon (H_ε) line is weak, as is the hydrogen-delta (H_δ).

If, as seems probable, the carbon-nitrogen cycle has been operating in such a star while its central temperature was about 20 million degrees, nuclei of C^{13}, N^{14}, and N^{15} were produced in amounts proportional to the relative probabilities of the intermediate steps of the cycle. After it has acted for a long time, the equilibrium ratio of N^{14}/C^{12} should be 20/1, that is, rich in nitrogen and relatively poor in carbon. The spectrum verifies this, and the carbon lines that might be expected in this region of the spectrum are not visible.

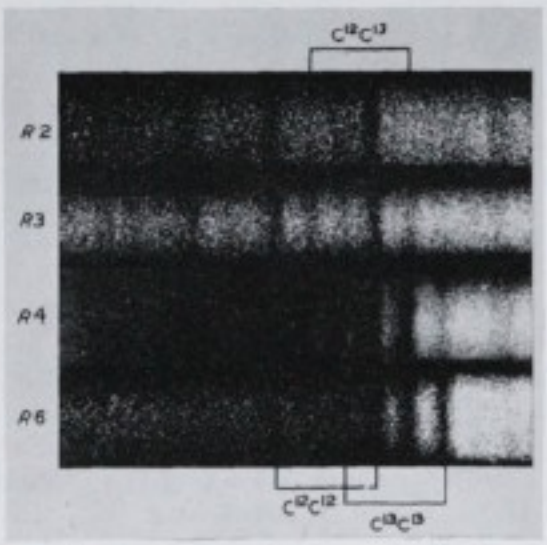
Another prediction from the equilibrium theory of the carbon-nitrogen cycle is that the abundance ratio of C^{13} to C^{12} should be 1/4. The terrestrial ratio is 1/90, and about the same value is observed in the solar atmosphere. Even though the carbon-nitrogen cycle may be active in the sun's interior at present, the abundant C^{13} nuclei have not had time to be carried to the surface by convection currents.

But in some late-type giant stars, McKellar has observed very strong bands produced by three kinds of diatomic carbon molecules. The first is made up of two C^{12} atoms, the second is a mixture of isotopes, $C^{12}C^{13}$, and the last is composed of two C^{13} atoms. Evidently in these stars mixing is more powerful than in the sun, and the C^{13} nuclei have been carried to the surface. The observed ratio of C^{13} to C^{12} is about 1/4, as predicted by theory. As seen in the uppermost of the *R*-type spectra reproduced here, some of McKellar's stars show little if any evidence of C^{13}. These stars are either younger or they had little mixing.

As for the betatron effect, which would produce the elements lithium, beryllium, and boron, McKellar says that to his knowledge only three out of a hundred carbon stars show the strong line of neutral lithium at 6707 angstroms. They are WZ Cassiopeiae, WX Cygni, and T Arae. Evidently for local betatrons to form on a star's surface, special conditions are required that are infrequently realized.

According to Fowler and Greenstein, the red giant stars—classes *M*, *N*, *R*, and *S*—give the most straightforward evidence for the synthesis of heavy elements. Many of them must have central temperatures of the order of a billion degrees, and their spectra are rich in molecules containing heavy atoms. Evidently C^{12} has been built up by the Be^8 reaction discussed last month, and there has been a synthesis of the heavy nuclei of the fourth, fifth and sixth periods of the periodic table.

Normal, relatively young *M* stars have their most abundant heavy elements in the "iron group," in the fourth period of the periodic table, with atomic numbers from 19 (potassium) to 36 (krypton). *M*-type spectra are characterized by strong bands of titanium oxide, titanium being element number 22. We have already seen that the carbon stars, *N* and *R*, are rich in heavy elements of many kinds. But it is in the *S* stars, where lines of elements of the fifth and sixth periods (atomic numbers 37 to 86) are stronger than normal, that element building seems most advanced.



In these spectra of R stars by Andrew McKellar, dark bands from different kinds of carbon molecules are labeled. The weakness of the C^{13} bands in the R2 star shows a marked rarity of this isotope, as compared with C^{12}. Dominion Astrophysical Observatory photograph with the 73-inch reflector.

Stars of class *S* are recognized by strong bands of zirconium oxide (instead of titanium oxide for *M* stars), and zirconium is element number 40, in the fifth period. Technetium, of atomic number 43, is also observed, even though it has a rapidly decaying radioactive nucleus. As already mentioned, its presence in *S* stars, the oldest giants with cool atmospheres, seems explainable only on the basis that it is being constantly replenished.

For their theory of an original hydrogen cloud being enriched continuously with heavy elements produced in stars, its authors claim only that it is not inconsistent with today's very limited knowledge of nuclear reactions in stars. They do not necessarily exclude an explosive origin of the universe, with atom building from an original "ylem."

On the astronomical side there are some difficulties that are clearly recognized. One is the great age of the sun, 4½ billion years or older. Do the abundant heavy elements in its atmosphere indicate that it is a second-generation star, formed from enriched interstellar gas? But the difference between the age of the galaxy, about six billion years, and the sun's own age seems too short for this.

If the sun is a first-generation star, the atmospheric abundances indicate more powerful internal element building than is possible at 20 million degrees; also, there may be more violent mixing by convection that can be reconciled with the observed intensities of the lithium lines and the carbon isotope ratio in the solar atmosphere.

Thus, there remains a suspicion stressed especially by W. Baade that the original interstellar medium was already enriched when the oldest stars of the spiral arms (like the sun) were produced. It is also possible that different distant regions of the original cloud—for example, near the galactic nucleus and in the halo—had different chemical compositions. If so, stars from these regions that stray into our neighborhood, RR Lyrae variables, high-velocity stars, and so on, might make us mistake a real difference of original composition for the apparent result of evolution.

ASTRONOMICAL SCRAPBOOK

Surveying the Moon

IT IS TIME that proper recognition is given to a little publicized but important part of modern astronomy's growing interest in the moon. Currently, some 800 pages are devoted each year in astronomical journals and observatory publications to one phase or another of lunar research, and books about the moon fill roughly the same bulk. However, only a small portion of this varied literature from all parts of the world comes to the amateur's attention, and what he does see are predominantly descriptive studies of lunar surface formations.

By contrast, much less is heard of the field that might be called selenodesy—the lunar counterpart of the terrestrial science of geodesy. It deals with matters like the size and shape of the moon, the selenographic co-ordinates of surface formations, crater diameters, and mountain heights. Essentially, it is a quantitative rather than a descriptive approach to the problems of the configuration of the moon's surface.

The usefulness of such quantitative information needs little stressing. For one thing, any general theory of the origin and evolution of lunar craters, if it is to gain general acceptance, must account for numerical data on crater dimensions, wall slopes, and distribution over the moon's surface. From a practical viewpoint, an accurate lunar map cannot be drawn—even from photographs—unless the co-ordinates of numerous reference points are known, just as in the case of terrestrial cartography.

The small crater Mosting A, pointed out by the white lines, is the lunar feature whose position has been most precisely measured. It is close to the center of the moon's disk. To its left is the large ruined ring, Flammarion, and part of Ptolemaeus is at the upper left. This photograph, made when the sun was 11 degrees above the horizon of Mosting A, is reproduced from F. Hayn's "Selenographische Koordinaten."

Selenodesy is an active field today, and at least four observatories give it an important place on their programs. At the U. S. Naval Observatory, C. B. Watts is now finishing his elaborate topographical atlas of the marginal zone of the moon. Its immediate purpose is to portray the detailed contour of the lunar edge under all stages of optical libration, so observations of the moon's position can be freed from errors due to limb irregularities. At Vienna, extensive measurements are under way of the heights of lunar mountains —both height relative to a mountain's immediate surroundings, and absolute height referred to the moon's center. Astronomers at Krakow, Poland, and Kazan, U.S.S.R., are studying the moon's physical libration—the very small irregularity in the moon's rotation caused by the earth's varying attraction on the slightly ellipsoidal body of the moon.

Besides these investigations by professional astronomers, important work is being carried out by a British amateur, D. W. G. Arthur, who is an active member of the lunar section of the British Astronomical Association. His specialty is the measurement of the positions of reference points on the moon, to serve in the preparation of improved maps.

The original foundation of his work was the very precise determination of the selenographic latitudes and longitudes of a few craters, such as Mösting A, by the German astronomers J. H. Franz and F. Hayn near the turn of the century. Their laborious visual measurements were made with heliometers, and gave fundamental points to which other lunar features could be referred. The next step, carried out just before World War I by Franz, and in England by S. A. Saunder, was the determination from large-scale photographs of the positions of about 3,000 additional points, to an average accuracy of 1,000 feet on the moon's surface.

Modern charts, like H. P. Wilkins' 300-inch map of the moon, depend for their skeletons on these bench marks. But even these 3,000 points are not enough for large-scale, highly detailed charts of complex portions of the moon.

Mr. Arthur is filling this need in a series of *Contributions to Selenography*, of which five parts have appeared since 1953. His measurements are made on glass copies of Mount Wilson and Lick Observatory photographs. Using a 6-power comparator, he determines the plate co-ordinates for each lunar object with an accuracy of about 0.01 millimeter.

Next, these measured co-ordinates are converted to lunar co-ordinates. Following modern practice, Mr. Arthur does not use selenographic longitude and latitude, but the much more convenient rectangular co-ordinates equivalent to them. Instead of the older trigonometric conversion formulas, which were cumbersome and tedious, Mr. Arthur uses much more convenient formulas, adapted for use with a desk computing machine, which he presents in his *Contribution No. 4*. Thanks to this simplified method, mass production is possible.

The campaign has already borne abundant fruit. *Contribution No. 2* catalogues about 490 craters, craterlets, pits, and peaks on the surface of Mare Imbrium, and *No. 3* lists the positions of some 300 features in Oceanus Procellarum. In the past, wide stretches of the latter sea were lacking in control points, making its charts more or less unreliable. *Contribution No. 5* is a triangulation of the intricate detail in the neighborhood of the crater Copernicus, giving the positions of 580 points.

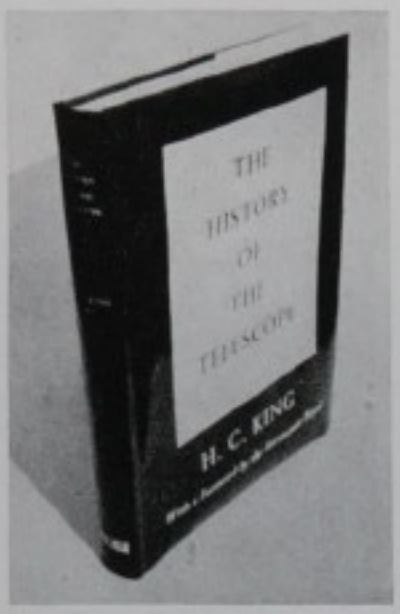
These series of measurements, carried out with professional care and thoroughness, are parts of a large program that is ultimately to cover the entire visible face of our satellite. In addition, Mr. Arthur has made a great many unpublished measurements of mountain heights, and has edited, as his *Contribution No. 1*, the late J. Young's useful catalogue of the diameters of about 1,400 craters.

The whole endeavor is an excellent example of the ample scope of selenography for the hard-working amateur who wants to carve out an original and useful field. The permanent value of Mr. Arthur's work makes it unfortunate that the *Contributions to Selenography* are only being privately published in editions as small as 50; copies may be very hard to find some years hence. Observatories and institutions which are interested in lunar research can obtain them free of charge (except for postage) from Mr. D. W. G. Arthur, 17 Waterloo Rd., Wokingham, Berks, England.

JOSEPH ASHBROOK

FACING PICTURE: The northeastern portion of the waning moon, age 24.3 days, enlarged from J. H. Moore and J. F. Chappell's negative of August 20, 1938, taken with the Lick Observatory 36-inch refractor. This is a continuation of a series of crescent views which began in the February issue. Near the middle is Aristarchus, brightest of all lunar craters. Surrounding it is the gray plain Oceanus Procellarum, which covers most of the picture, merging into Sinus Roris at the extreme lower left. The prominent crater 3½ inches from the upper left corner is Kepler, from which bright rays fan out. One ray runs horizontally to the right toward the crater Reiner and the curious bright marking known as Reiner Gamma.

Complete Your Astronomy Library



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Amateur Astronomers

NORTH CENTRAL CONVENTION

With the Beloit Astronomical Society acting as host, the tenth annual convention of the North Central Region of the Astronomical League was held on May 19th at Beloit, Wisc., with 90 participants, representing nine societies in Wisconsin, Illinois, and Minnesota.

The morning session was devoted to a talk by Richard Fink, Milwaukee, on photographing comets, and one by Gordon Hall, Milwaukee, on circles and controls for a portable 6-inch telescope. Armand Spitz, co-ordinator of visual observations of artificial satellites, also spoke.

After lunch, several junior astronomers gave an interesting program. Howard Gould and Craig Shur, Minneapolis, showed a film and gave a commentary on the eclipse of June 20, 1954, and on the activities of the Minneapolis junior astronomers. The afternoon session concluded with a film by Edward Halbach, Milwaukee, of his 1955 eclipse expedition in Africa.

At the convention banquet, Dr. Ralph Huffer, director of Beloit College Observatory, gave a talk on two famous astronomers, T. C. Chamberlin and Henrietta Leavitt, both of whom lived in Beloit at one time. The balance of the evening was spent observing through the college's telescope, and with amateurs' instruments on the observatory lawn.

Re-elected as officers were Roy L. Dodd, Milwaukee, chairman; H. B. Porterfield, Madison, vice-chairman; and the undersigned, secretary-treasurer. Robert G. Johnsson, Chicago, continues as regional representative.

MRS. RALPH BUCKSTAFF
1039 N. Main St.
Oshkosh, Wisc.

MIDDLE EAST CONVENTION

Ninety registrations for the Middle East Region convention of the Astronomical League, held May 4-6 at Washington, D. C., made this the largest-attended meeting in the region's history.

Among the papers given on the opening day was an account of the 1955 African eclipse expedition by Adam L. Ott, Jr., Pittsburgh, Pa.; one on the surface of the moon by Rolland R. LaPelle, Meadville, Pa.; and one on tektites by Ralph Stair, Washington, D. C.

The main speech at the convention banquet was "The International Geophysical Year and the Space Frontier," by Dr. Homer E. Newell, Jr., Naval Research Laboratory.

On the final day of the three-day meeting, G. R. Wright, chairman of the national advisory committee for the visual observations of satellites, conducted a session on the tracking program for amateurs. Armand N. Spitz, co-ordinator of visual satellite observations, also took part.

At the closing business meeting, the following were elected for the coming year: Charles H. LeRoy, Pittsburgh, Pa., chairman; Dana K. Law, Washington, D. C., vice-chairman; Mrs. Ione Alston, Washington, D. C., secretary; and Thomas Ogburn, III, Richmond, Va., treasurer.

ELIZABETH M. FAZEKAS
3900 16th St. N. W.
Washington 11, D. C.

THIS MONTH'S MEETINGS

Long Beach, Calif.: Excelsior Telescope Club, 7:30 p.m., Menifee Valley Observatory. Aug. 11, star party, Claude Carpenter, "Variable Stars."

Whittier, Calif.: Whittier Amateur Astronomers Association, 7:30 p.m., Bailey School building. Aug. 7, Dr. C. H. Cleminshaw, Griffith Observatory, "The Solar System."

GREAT LAKES CONVENTION

On the weekend of September 1-2, the Great Lakes Region of the Astronomical League will convene in Indianapolis, with the Indiana Astronomical Society as host. Talks will be given on tracking of the artificial satellite, on Mars, and other subjects. On Saturday evening, Dr. Harry Crull, Butler University, will address the convention at the Holcomb Observatory and Planetarium, where delegates can observe through the 38-inch Fecker reflector.

On Sunday afternoon, there is to be a junior session and an exhibition, followed by a trip to Goethe Link Observatory at Brooklyn, Ind., for a picnic and observing with the 36-inch telescope. Dr. James Cuffey, Indiana University, will give a talk.

Some of the sessions are to be held at Union Hall of the Indiana University Medical Center, where room accommodations are available at $5.00 single, $7.00 double. The registration fee until August 1st is $1.50 per person, after that $2.00; it may be sent to Ernest Davidson, 5521 Indianola Ave., Indianapolis, Ind. All interested amateurs, whether or not members of league societies, are invited to attend the convention.

WHEELING, W. VA.

The Oglebay Astronomical Association was formed in 1930, by a group of Wheeling businessmen. We use the facilities of Speidel Observatory, sponsored by the Oglebay Institute, an educational and cultural organization. There are 25 active members at present. Membership is open to anyone of any age, and there are no dues.

Our meetings are held on the first and third Thursdays at 8 o'clock in the auditorium of the Brooks Nature Center in

Oglebay Park. In addition to regular observing programs, the society maintains a fully equipped optical workshop in the center.

ROBERT W. SCHRAMM
Speidel Observatory
Oglebay Institute
Wheeling, W. Va.

SAN FERNANDO JUNIORS

The San Fernando Valley Astronomical Society has been active since April, 1953. We are of high-school age and meet every other Saturday at a member's home. New members are always welcome.

We own or have under construction three 4-inch reflectors, five 6-inch, three 8-inch, two 10-inch, and one 12½-inch. We are also building a 7-inch astrographic telescope and a 7-inch Gregorian. With a heliostat, solar phenomena have been recorded every clear day for the past three years. All of our equipment, except a 4⅝-inch refractor, was made by our members.

Although sky transparency here in the valley is poor, there is better-than-average steadiness, and many fine lunar and planetary observations have been made. We plan to observe Mars this summer, at times from a mountain cabin of one of our members.

We would appreciate correspondence from other societies.

ROGER BLAND
10840 Kling St.
North Hollywood, Calif.

OTTERBEIN'S NEW OBSERVATORY

The Weitkamp Observatory and Planetarium of Otterbein College, Westerville, Ohio, was dedicated on June 1st. The building was constructed by the college staff under the direction of Sanders Frye, and contains a 16-inch Astrola reflector and a Model A Spitz planetarium.

Leon Zechiel is director of the new facilities, which will be available to the general public and to local schools. Building and instruments were donated by Dr. A. W. Weitkamp, of Los Angeles, Calif., in memory of his wife.

The dedication address was given by Armand N. Spitz, who was awarded an honorary degree of doctor of science at the Otterbein College commencement exercises on June 4th.

Planetarium Notes

(Most planetariums give group and special showings by appointment.)

BALTIMORE: *Davis Planetarium.* Maryland Academy of Sciences, Enoch Pratt Library Building, 400 Cathedral St., Baltimore 1, Md., Mulberry 2370.

SCHEDULE: Monday (Sept.-June), 3:45 p.m.; Thursday, 7:15, 7:45, 9:00 p.m. Admission free. Spitz projector. Director, Paul S. Watson.

BLOOMFIELD HILLS, MICH.: *McMath Planetarium.* Cranbrook Institute of Science, Bloomfield Hills, Mich.

SCHEDULE: Saturday and Sunday, 2:30 and 3:45 p.m. Spitz projector. In charge, James Carmel.

BUFFALO: *Buffalo Museum of Science Planetarium.* Humboldt Parkway, Buffalo, N. Y., GR-4100.

SCHEDULE: Sunday, 2:00 to 4:30 p.m. (except summer). Admission free. Spitz projector. Director, Fred Hall.

CHAPEL HILL: *Morehead Planetarium.* Univ. of North Carolina, Chapel Hill, N.C.

SCHEDULE: Daily at 8:30 p.m.; also 11 a.m. and 3 p.m. Saturdays, 3 and 4 p.m. Sundays. Zeiss projector. Manager, A. F. Jenzano.

CHARLESTON, W. VA.: *Hillis Townsend Planetarium,* Children's Museum, Public Library Building, Charleston, W. Va.

SCHEDULE: Saturday, 11 a.m. Admission free. Spitz projector. Director, Mrs. R. L. Sullivan.

CHICAGO: *Adler Planetarium.* 900 E. Achsah Bond Drive, Chicago 5, Ill., Wabash 2-1428.

SCHEDULE: Mondays through Saturdays, 11 a.m. and 3 p.m.; Tuesdays and Fridays, 8 p.m.; Sundays, 2 and 3:30 p.m. Zeiss projector. Director, Wagner Schlesinger.

DALLAS: *Dallas Planetarium.* Dallas Health Museum, Fair Park, Dallas 10, Tex., HA 8-5755.

SCHEDULE: Saturday, 11 a.m.; Sunday, 2:30 and 4:30 p.m. Spitz projector. Director, Mrs. Claudia Robinson.

DENVER: *Denver Museum of Natural History Planetarium.* City Park, Denver, Colo., East 2-1808.

SCHEDULE: Saturday and Sunday, 1 to 4:30 p.m. Spitz projector.

FT. WORTH: *Charlie M. Noble Planetarium.* Ft. Worth Children's Museum, 1501 Montgomery St., Ft. Worth, Tex., PA-1461.

SCHEDULE: Tuesday through Saturday, 11 a.m., 1:30 and 2:30 p.m.; Sunday, 2:30 p.m. Spitz projector. Director, William Hassler.

INDIANAPOLIS: *Holcomb Planetarium.* Butler University, Indianapolis 7, Ind.

SCHEDULE: Saturday and Sunday, 4 and 8 p.m. Spitz projector. Director, Harry E. Crull.

KANSAS CITY: *Kansas City Museum Planetarium.* 3218 Gladstone Blvd., Kansas City 23, Mo., Humboldt 3-8000.

SCHEDULE: Saturday and Sunday (except first weekend of month), 3 p.m. Spitz projector. Director, Kenneth W. Prescott.

LANCASTER, PA.: *North Museum and Planetarium.* Franklin and Marshall College, Lancaster, Pa.

SCHEDULE: Tuesday and Thursday, 8 p.m.; Saturday and Sunday, 3 p.m. Admission free. Spitz projector. Curator, John W. Price.

LAQUEY, MO.: *Tarbell Planetarium.* Inca Cave Park, Laquey, Mo.

SCHEDULE: Alternate Sundays, 1 to 6 p.m., continuous. Spitz projector. Director, E. D. Tarbell.

LOS ANGELES: *Griffith Observatory and Planetarium.* Griffith Park, P. O. Box 27787, Los Feliz Station, Los Angeles 27, Calif., Normandy 4-1191.

SCHEDULE: Daily, 3, 8, and 9:15 p.m.; extra shows on Saturday and Sunday, 4:15 p.m. Zeiss projector. Director, Dinsmore Alter.

MINNEAPOLIS: *Science Museum.* Minneapolis Public Library, 1001 Hennepin Ave., Minneapolis 3, Minn.

SCHEDULE: Saturday, 10 a.m. and 2 p.m. Admission free. Spitz projector. Curator of education, Maxine B. Haarstick.

NASHVILLE: *Sudekum Planetarium.* Children's Museum, 724 2nd Ave. S., Nashville 10, Tenn., 42-1858.

SCHEDULE: Sunday, 2:45, 3:30, 4:15. Spitz projector.

NEWARK: *Newark Museum Planetarium.* 49 Washington St., Newark 1, N. J., Mitchell 2-0011.

SCHEDULE: Monday, Wednesday, and Friday, 12:15 p.m. Admission free. Spitz projector. In charge, Ray Stein.

NEW YORK CITY: *American Museum—Hayden Planetarium.* 81st St. and Central Park West, New York 24, N. Y., Trafalgar 3-1300.

SCHEDULE: Mondays through Fridays, 2, 3:30, and 8:30 p.m.; Saturdays, 11 a.m., 1, 2, 3, 4, 5, and 8:30 p.m.; Sundays and holidays, 1, 2, 3, 4, 5, and 8:30 p.m. Zeiss projector. Chairman, J. M. Chamberlain.

PHILADELPHIA: *Fels Planetarium.* Franklin Institute, 20th St. at Benjamin Franklin Parkway, Philadelphia 3, Pa., Locust 4-3600.

SCHEDULE: Tuesdays through Sundays, 3 p.m.; Saturdays, 11 a.m.; Saturdays, Sundays, and holidays, 2 p.m.; Wednesdays, Fridays, and Saturdays, 8:30 p.m. Zeiss projector. Director, I. M. Levitt.

PITTSBURGH: *Buhl Planetarium and Institute of Popular Science.* Federal and West Ohio Sts., Pittsburgh 12, Pa., Fairfax 1-4300.

SCHEDULE: Mondays through Saturdays, 2:15 and 8:30 p.m.; Sundays, 2:15, 4:15 and 8:30 p.m. Zeiss projector. Director, Arthur L. Draper.

PORTLAND, ORE.: *Oregon Museum of Science and Industry Planetarium.* 908 N.E. Hassalo St., Portland 12, Ore., East 3807.

SCHEDULE: Saturday and Sunday, 3:00 p.m. Spitz projector.

PROVIDENCE: *Roger Williams Planetarium.* Roger Williams Park Museum, Providence 5, R. I., Williams 1-5640.

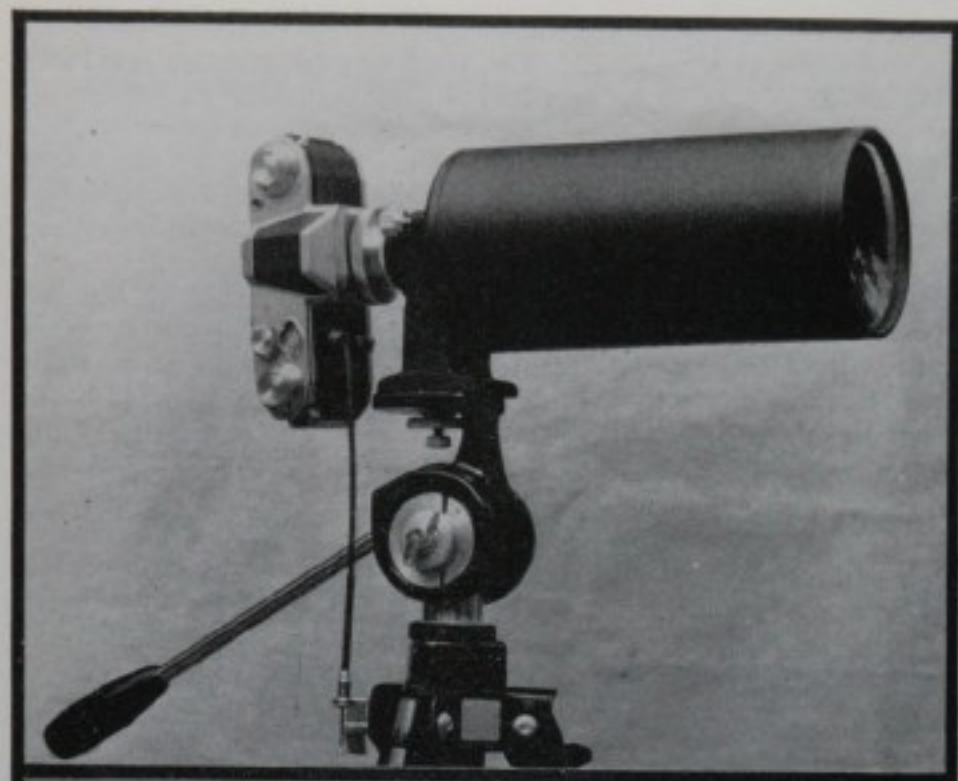
SCHEDULE: Saturdays, Sundays, and holidays, 3 and 4 p.m. (Oct.-June). Admission free. Spitz projector. Director, Maribelle Cormack.

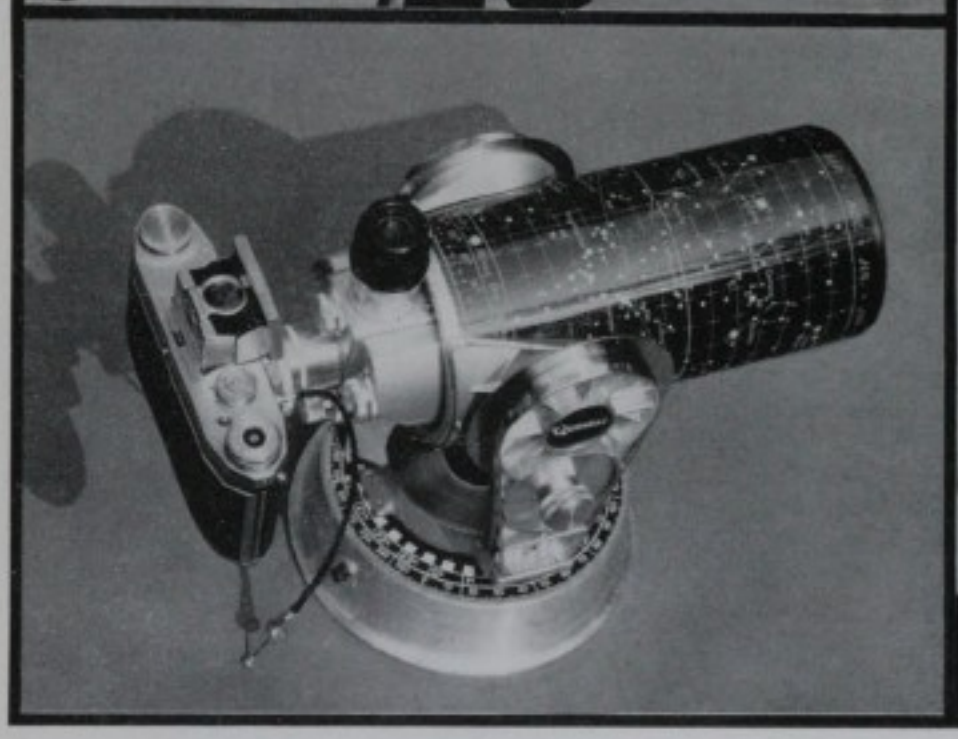
SAN FRANCISCO: *Morrison Planetarium.* California Academy of Sciences, Golden Gate Park, San Francisco 18, Calif., Bayview 1-5100.

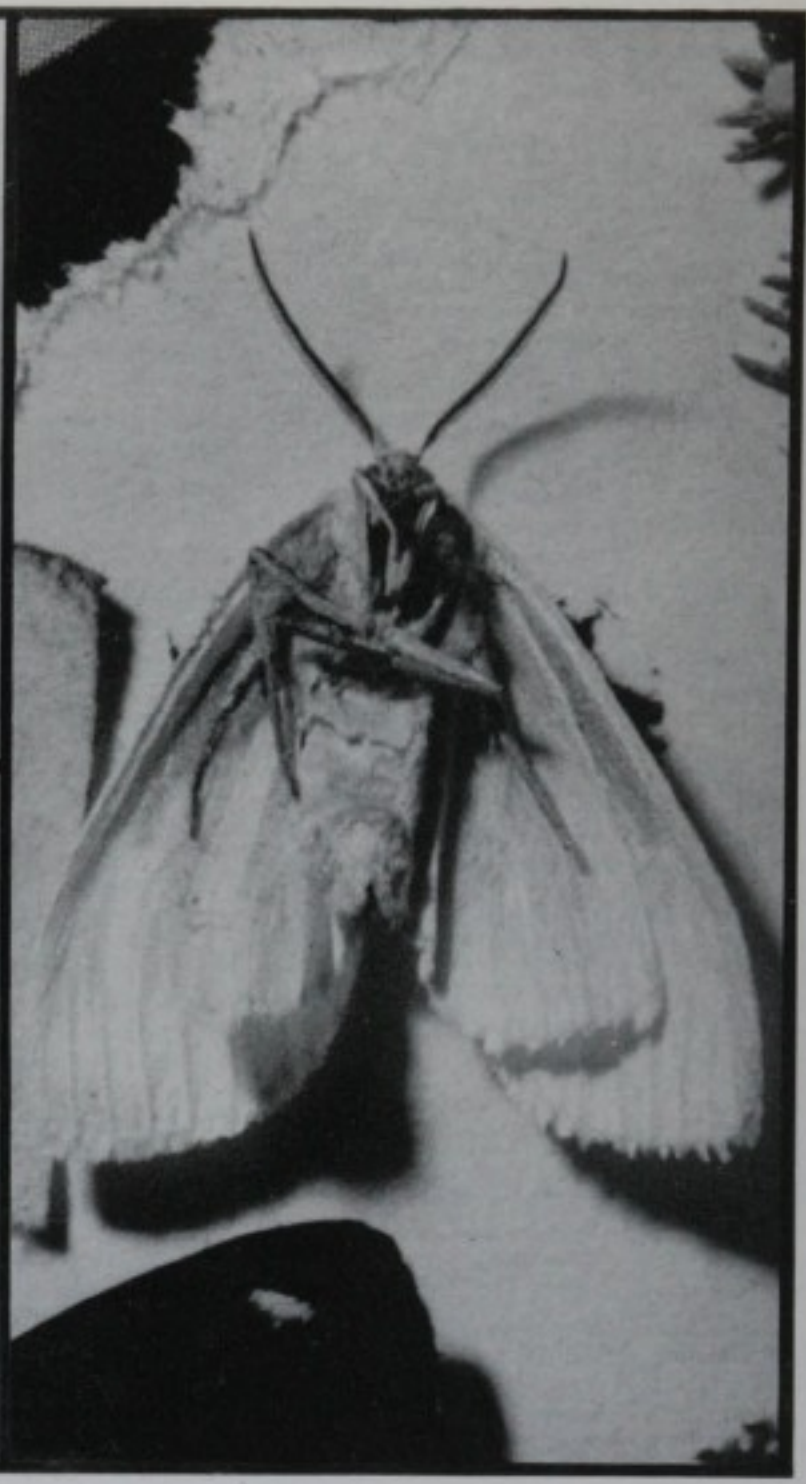
SCHEDULE: Daily (except Monday and Tuesday) at 3:30 and 8:30 p.m.; also at 2 p.m. on Saturdays, Sundays, and holidays. Academy projector. Curator, George W. Bunton.

SPRINGFIELD, MASS.: *Seymour Planetarium.* Museum of Natural History, Springfield 5, Mass.

SCHEDULE: Tuesdays, Thursdays, and Saturdays at 3 p.m.; Tuesday evenings at 8:30 p.m.; special star stories for children on Saturdays at 2 p.m. Admission free. Korkosz projector. Director, F. Korkosz.







QUESTAR AND THE LITTLE MOTH

The right-hand photograph is an enlarged portion of the first picture ever taken with the first experimental Questar. We made it indoors, back in 1947, at a distance of 18 feet.

On that occasion we had just set up the lens and mirror of this newly invented catadioptric telescope in a test rig—a tubeless, open-air sort of arrangement, and had been using it on the sky and landscape. We were pretty excited about what we had been seeing with it—it was a little tiger, with more sharpness and power than we had ever imagined possible from an instrument so incredibly short and handy.

Then we began to look at nearby objects, and were astounded to see how beautifully the new optics performed at the extreme short range of a dozen feet or so. We'd never heard of anybody trying to turn the full resolving power of an astronomical telescope on objects so near. (Older types are mechanically and optically all wrong for such work, their eyepieces requiring great rearward extension. Questar's focusing is internal; the eyepiece remains fixed.) Suddenly we realized that we had a whole new kind of instrument, a sort of long-distance microscope. Moreover, this near view would give us a chance to test Questar's photographic powers most conveniently indoors in quiet air.

We pasted some scraps of torn paper, a sprig of heather, a butterfly and the little thumbnail-size moth to a card 18 feet away. Instead of using an eyepiece, we focused the image on the ground glass of an old bellows camera, using the Questar optics in their temporary setup as the lens. We took two shots, and developed the films. The negatives looked good, so we dried them and made prints. Our eye was caught by the antennae of this tiny moth, so we made the enlarged print shown above. Seventy-two tiny branches were clearly visible on the right-hand antenna.

We remember going to bed tired but happy that early morning. What an instrument! It would photograph just about everything you could see with it, without fuss or filters.

Today, Questar's photographic possibilities are just being explored. There's a Questar at the Corning Glass labs taking movies of miniature crucibles of molten glass at 3,000°. An increasing number of Questar owners want cameras for the fully mounted Questar and the new 31 oz. Field Model, both shown above. Since Questar's resolution attains theoretical perfection for its aperture, it is, of course, a phenomenally sharp telephoto lens of 1,077-mm. focal length, 42.4 inches. With so sharp a lens, the skill and experience of the photographer is indeed challenged.

We carry in stock a camera adapter to fit the two single lens reflex cameras pictured above, which are well suited for this purpose. We would be pleased to have you consult us about your special requirements.

Questar Field Model in leather case, $495; Questar 40x Eyepiece, $20; Questar Wide-Field Erfle Eyepiece, $25; Questar Eyepiece Adapter Tube, $6.00 (only one required); Questar Camera Adapter, $7.50; Questar Sun Filter, $25; De Luxe Questar with all accessories in handmade English leather case, $995. All are shipped insured and prepaid in the continental United States.

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BOOKS AND THE SKY

TEMPERATURE, ITS MEASUREMENT AND CONTROL IN SCIENCE AND INDUSTRY. VOLUME II.

Hugh C. Wolfe, editor. Reinhold Publishing Corp., New York, 1955. 467 pages. $12.00.

LIKE many other concepts in physical science, that of temperature owes much of its theoretical clarification and practical development to the challenge of outstanding problems in astronomy. As recently as near the beginning of this century, estimates of the sun's effective temperature ranged from 1,500° to 10,000,000° absolute. To resolve these inconsistencies, there were developed many theories relating radiation (which can be measured directly) and temperature, culminating in the exact laws of Stefan, Wien, and Planck.

Indeed, even some modern statements about astronomical temperatures still seem inconsistent, for example, that the sun's photosphere is at 6,000° while the corona is at 1,000,000°, until it is realized that here two different definitions of temperature, *radiation* and *kinetic*, respectively, are being used. Since the first is measured essentially by the photon energy *per unit volume*, while the second is by the kinetic energy *per particle*, the latter may be much higher for low density gases, even at greater distances from the same source of energy.

This and many other aspects of temperature related to astronomy and physics are here given comprehensive, up-to-date description by a score of experts. The present volume is a record of the proceedings of the third international symposium on temperature held at the National Bureau of Standards in October, 1954, and is a continuation of Volume I reporting the second symposium (1939). Other sponsors were the American Institute of Physics, represented by the editor, and the Office of Ordnance Research, U. S. Army.

Along with discussions of the meanings of temperature and methods of measuring it are many descriptive examples: from cold near the absolute zero of interstellar space to the tens of millions of degrees inside a star or an atomic bomb explosion; also how and why such temperatures are produced, whether in nature or in the laboratory.

Astronomical examples in the chapter on astrophysical temperatures, by Cecilia Payne-Gaposchkin, explain concepts and modes of attack on temperature problems appearing again and again throughout the book. The necessity, in astronomy, of measuring and describing conditions entirely out of one's reach stimulated the development of laboratory ideas and procedures. The latter, in turn, were fed back to produce progress in astronomy and related out-of-reach problems such as the temperatures of the earth's upper atmosphere. The latter question, of special interest to astronomers, is discussed by Homer E. Newell, Jr., who is now science program co-ordinator of the artificial satellite project.

Astronomers who enjoy setting up and testing instruments will find much on this subject in Section IV of the book, which is devoted to experimental measurements. The chapter on temperature measurement in engineering, by Harold J. Hoge, surveys all practical means, from the well-known weather thermometer to the more sophisticated optical pyrometer. The latter instrument, by the way, might well become a favorite instrument of amateur astronomers. For instance, the present reviewer, using an optical pyrometer costing no more than a 2-inch telescope, once found that a few sights on the sun gave its temperature within 100 degrees or so of the accepted value. Substitution of a larger optical system should make possible measurements of the temperature of sunspots and even finer details.

Finally, for the more serious student, the book has both an author and subject index and most chapters have extensive bibliographies. The physical makeup of the book is excellent; there are few typographical errors, and the numerous curves, photographs, and summarizing tables as-

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RAYMOND H. WILSON, JR.
Naval Research Laboratory

ELECTRONICS

A. W. Keen. Philosophical Library, Inc., New York, 1956. 256 pages. $7.50.

THE SUBJECT of electronics concerns electrons in action. It is a subdivision of electrical technology embracing principally electrons that move through space, as distinguished from electrons moving as electric currents through conventional conductors. A well-known application is the vacuum tube, where a heated element in a vacuum emits electrons that are attracted through space to a positively charged plate.

With the advent of radio telescopes, with electronic photocells now standard observatory equipment, with speedy electronic computors to do tedious calculations—to mention only a few applications—everyone seriously interested in astronomy has imperative reasons to know about electronics.

A British radio engineer, A. W. Keen, has ably surveyed the latest developments in electronics in this book. It is a non-mathematical, descriptive treatment of the basic inventions employing electronics. Explanations are given of many kinds of vacuum tubes, their purposes and functions, together with the various types of circuits in which they can be incorporated. Commercial instruments are described, including radio and television transmitting and receiving sets, magnetic tape recorders, digital computers, nuclear reactors, X-ray machines, fluorescent lamps, navigation aids, transistors, solar batteries, and Geiger counters.

Numerous applications of electronic tubes for switching, amplifying, rectifying, and metering are cited, and these suggest new practical uses in astronomy.

Although the jacket cover states that the book is written in elementary terms, it is in reality addressed to readers who previously have had some training in basic electrical technology. Many abbreviated expressions and specialized symbols are frequently used, with the apparent assumption that the reader is already familiar with them. An elementary student will experience some difficulty here.

Reading this work will give a better comprehension of the physical nature of light and other stellar radiations, which extend the full length of the electromagnetic spectrum from ultraviolet light to radio waves.

The book is appropriately illustrated with photographs and diagrams. It is carefully written and well organized. A more comprehensive index would be desirable.

VICTOR W. KILLICK
Sacramento Valley Astronomical Society

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Notes on Basic Optics — XX

T. Catadioptric Systems

An optical instrument is said to be catadioptric if it contains both image-forming mirrors and lenses working in combination. In a sense, any reflecting telescope is a catadioptric system if we include the eyepiece, but the term is generally reserved for those systems in which mirrors and lenses combine to form the primary image. There are too many specialized instruments of this type to be described in detail here. Several catadioptric forms, however, have been used or suggested for astronomical telescopes, because of their attractive properties. A few of the more widely known types will be presented in this month's installment and the next.

It is a common misconception that lens-mirror combinations make aberrationless instruments. Actually, however, most catadioptric systems are, from their basic form, inherently free from certain third-order aberrations; some other aberrations are sufficiently small to be left uncorrected. Usually the catadioptric system that is to be used for a particular application is decided by the nature and amount of the uncorrected rays.

The important consideration of flatness of field is best explained in terms of the relation between Petzval curvature and astigmatism. This was discussed in the May, 1955, installment, from which Fig. 47 is reproduced for the reader's convenience. Here, as in general, there are two separate and distinct focal surfaces—the tangential surface, where tangential fans of rays yield the best image, and the sagittal surface, where sagittal rays are best imaged. When astigmatism exists, the tangential surface will always be three times farther from the Petzval surface than the sagittal one is. In an optical system with no astigmatism, these two focal surfaces coincide with each other and with the Petzval surface.

If a system has a flat Petzval surface, and if astigmatism is negligible, then we have a truly flat field, a condition much to be desired in photographic instruments. Some so-called flat-field systems are designed in which the tangential surface is flat, but these may have measurable Petzval curvature. This is a fairly common practical solution to the problem of

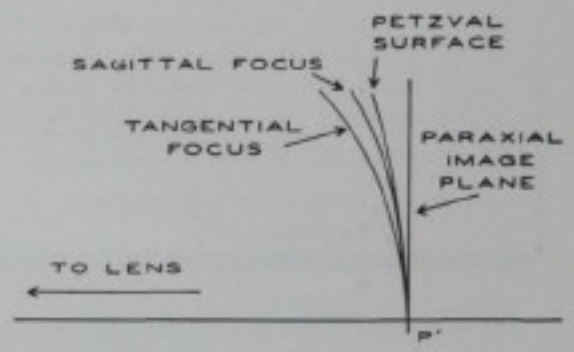

Fig. 47. The several kinds of focal surfaces of an optical system.

flatness of field. In occasional instruments, the tangential and sagittal surface may be bent symmetrically about a plane, in which case the surface of best definition is that plane, but astigmatism is present. In other systems, such as the Schmidt, astigmatism is eliminated and the image lies on the curved Petzval surface, so that the photographic plate must be shaped to fit this surface.

The catadioptric systems of most interest to astronomers may now be considered in turn.

1. **The Schmidt Camera.** The best-known catadioptric system in the astronomical field is the Schmidt type. It is named after Bernhard Schmidt, who introduced it as a fast wide-angle camera about 25 years ago (see *Sky and Telescope*, November, 1955, page 4). However, G. A. H. Kellner in 1910 had patented a similar system for use as a collimator projector (Fig. 60). Perhaps one should therefore refer to the Kellner-Schmidt, but the simpler term is so well known that we shall use it here.

As shown in Fig. 59, the primary image-

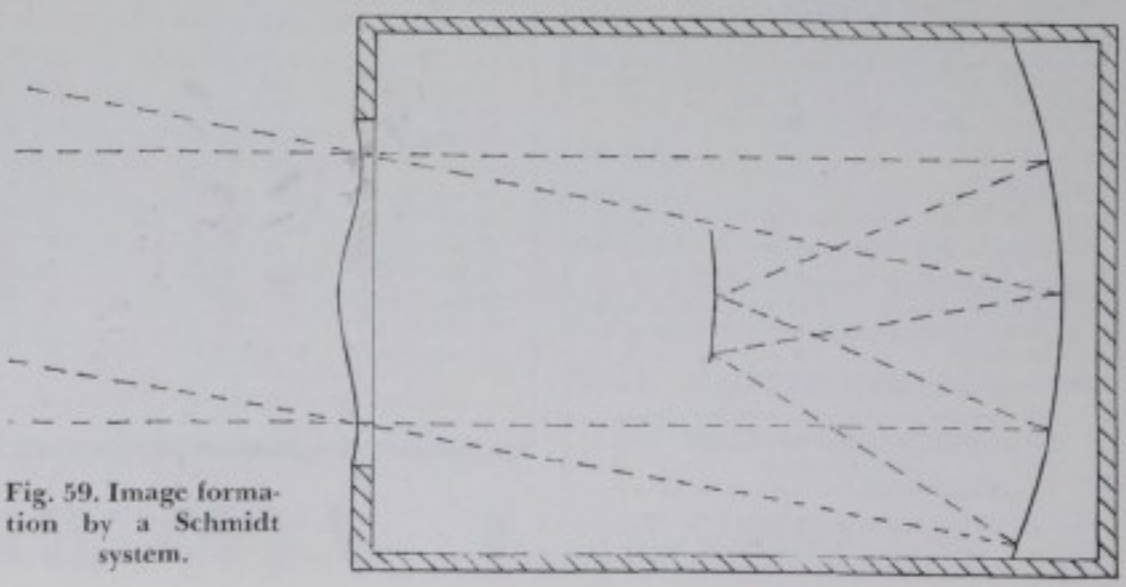

Fig. 59. Image formation by a Schmidt system.

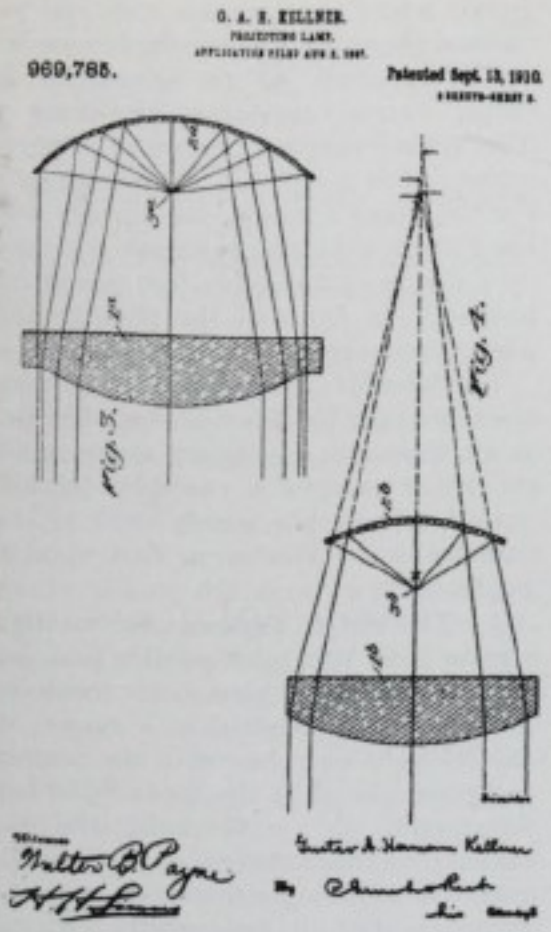

Fig. 60. The Kellner patent.

forming element of the Schmidt camera is a concave spherical mirror, which is free of chromatic aberration, and, when an aperture stop is used at the center of curvature, is also free from coma and astigmatism. These valuable properties are retained in the Schmidt system by using a thin correcting plate as the aperture stop. This plate neutralizes the otherwise intolerably large spherical aberration of the mirror.

Usually the correcting plate has one surface flat, and the other is curved to deviate the rays of an axially concentric bundle in such a way that the mirror brings them to an exact focus. The spherical aberration of a concave spherical mirror has the result (shown in Fig. 56 of May) that the focus becomes shorter as we proceed from the axis to the edge of the mirror. Hence the Schmidt corrector will require a form that gives it increasingly negative power as we go from the axis to the edge of the aperture.

The correcting plate will have some point of zero power, where the two surfaces of the plate are parallel. This point

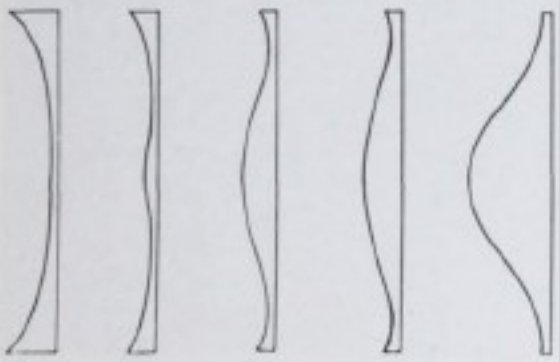

Fig. 61. Schmidt correcting plate forms, drawn with exaggerated curves.

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can be chosen arbitrarily, and the correcting plate may take any one of a wide variety of forms, as shown in Fig. 61. At the extreme left is the form for which all rays are brought to the paraxial focus, and at the extreme right is a correcting plate for which all the rays come to the marginal focus.

Some of the possible shapes of correcting plates are harder to make than others. Near the extremes shown in Fig. 60, the off-axis image quality is poorer. The shape most commonly chosen is the middle one; for this the zero-power zone is distant from the center of the plate by 0.707 times its radius.

To the astronomer, the Schmidt camera is valuable as an inexpensive, wide-angle, high-speed instrument with a sealed tube. While the expense of mounting is increased by the great tube length—twice the focal length—the glass of the corrector is cheaper than that for an objective of the same aperture. Many successful small Schmidts have correcting plates made of high-quality plate glass.

Despite its nonspherical curve, the thin correcting plate is well within the capabilities of an experienced telescope maker, as is evident from the many excellent instruments that amateurs have constructed. Unfortunately, some amateurs make their Schmidts with too small a focal ratio, under the impression that speed is the purpose of the Schmidt. A less extreme ratio, say f/3 or slightly longer, gives a larger photographic scale and the residual aberrations are negligibly small.

The drawback of the Schmidt is its strong Petzval curvature, producing a focal surface that is a portion of a sphere whose radius is equal to the focal length. For long-focus Schmidts, the curve is shallow enough to be approximately corrected by a simple plano-convex lens placed immediately in front of the photographic plate, plane side toward the emulsion.

The Schmidt camera has many applications, not only for direct photography but as an important laboratory accessory for the astronomer. For example, Schmidt optical systems are widely used as collimators and cameras in fast spectrographs.

2. **The Wright Camera.** An investigation by F. B. Wright of possible positions of the correcting plate and forms of primary mirror resulted in a camera of the Schmidt type, but with the correcting plate placed at the focus (just half the length of the Schmidt) and the primary mirror altered to an oblate spheroid. Although this gives a plane Petzval surface it reintroduces astigmatism to the system and has a color error twice that of a Schmidt of equal speed, and in practice this instrument is limited to f/3 or longer focal ratios. However, by means of a single support through the center of the correcting plate, a diagonal can be placed in front of the focus (avoiding the usual spider diffraction) and the

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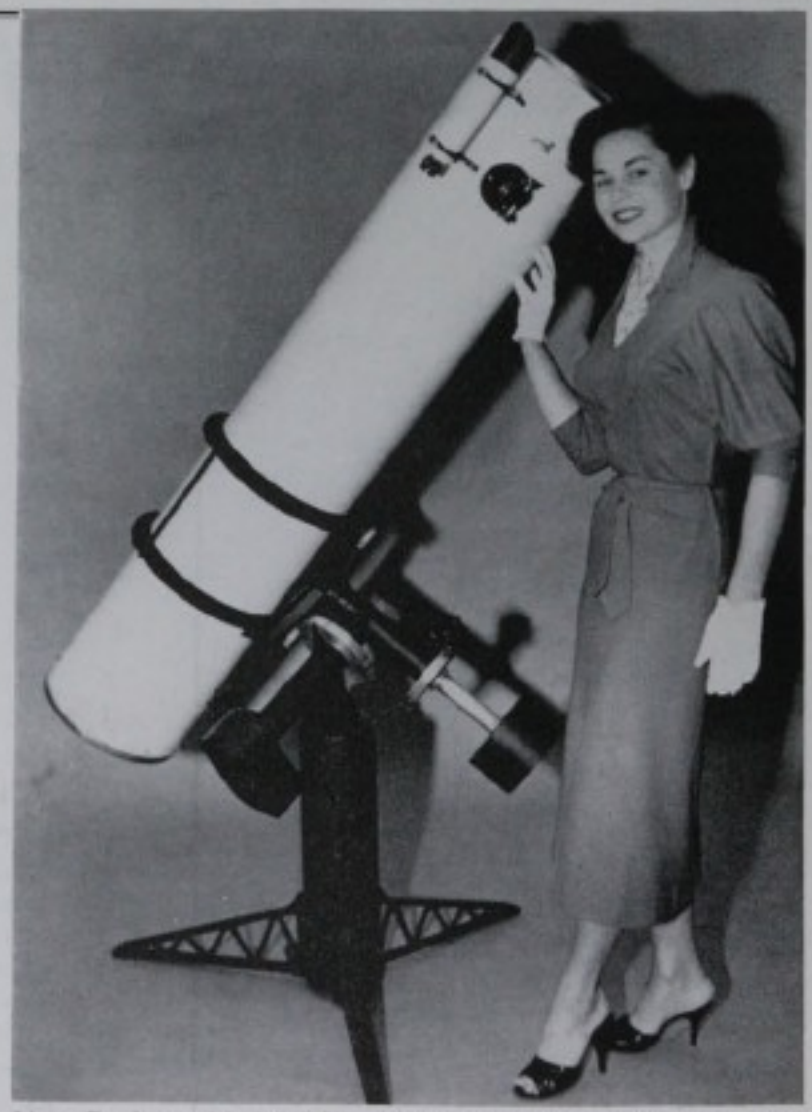

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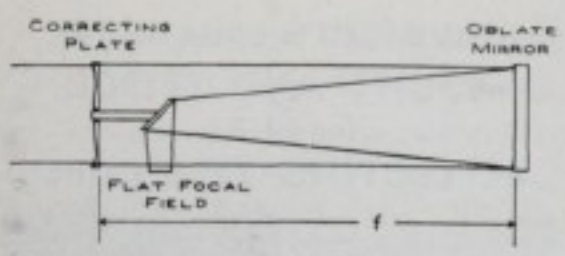

Fig. 62. The Wright camera, set up to be used as a Newtonian telescope.

instrument can be used as a Newtonian telescope.

This type is also well suited to amateur construction in spite of the necessity of figuring both the mirror and correcting plate. The oblate surface of the primary has almost exactly the correction of a paraboloid of the same focal ratio, but with an opposite slope, a hill in the center and a turned-up edge zone with a smooth progression from center to edge. At about f/4, good visual and photographic work can be accomplished with the Wright camera.

With the breaking of photographic plates by bending eliminated, it is not necessary to use film as in the amateur's Schmidt. Film often buckles, moreover, and fails to conform exactly to a curved focal surface. Because of the flat field, a number of Wright systems have been built for parallel-light projection of resolution grids and charts.

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WRIGHT CAMERA

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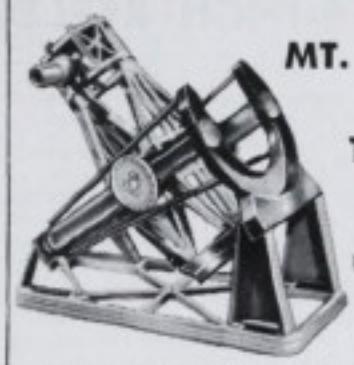

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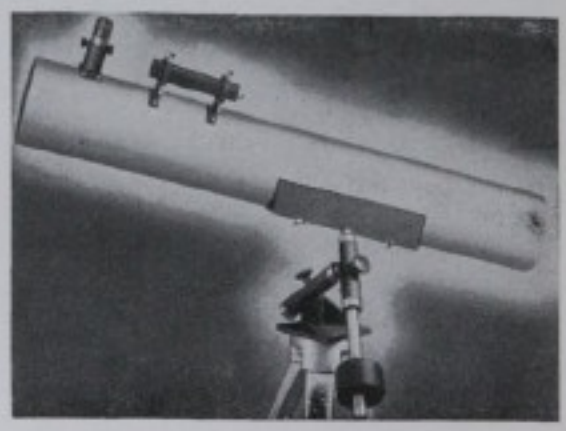

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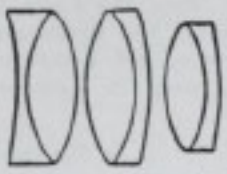

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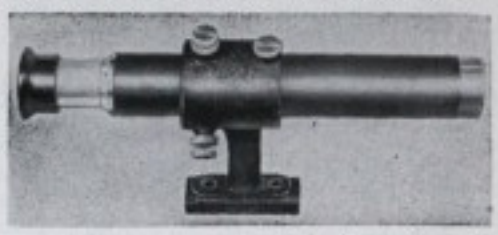

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OBSERVER'S PAGE

Universal time is used unless otherwise noted.

A Travel Guide for Amateur Observers of Mars

DURING this month and next, the unusual closeness of Mars to the earth invites amateurs to observe the planet with moderate-sized telescopes. As the Graphic Time Table of Mars on page 257 of the April issue shows, on September 7th the red planet will be only 35,200,000 miles distant.

Near this time, even a 3-inch refractor will reveal some of the larger dark markings on the planet, such as Syrtis Major. However, an aperture of about six inches will be needed to show much detail, and an 8- or 10-inch telescope can prove highly effective in the hands of a good observer. Yet those who can study the planet with adequate instruments may find difficulty comparing their drawings with maps of the planet unless they know the facts discussed here. Also, if inspection of a specific Martian feature is planned, it is necessary to know when it will be favorably placed for view.

These difficulties arise mainly from the planet's rotation. Mars turns once on its axis in $24^h\ 37^m\ 23^s$ with respect to the stars, but as viewed from the moving earth the apparent (synodic) rotation period is slightly longer, averaging $24^h\ 39^m$. Therefore, a marking seen tonight on the central meridian of Mars will reach it 39 minutes later tomorrow night. This drift of Martian markings across the planet's disk is from right to left as viewed in an inverting telescope by an observer on the Northern Hemisphere of the earth.

The location of a feature on the spherical surface of Mars can be specified by its *aerographic* latitude and longitude, which are analogous to the *geographical* coordinates of a place, except that longitude on Mars is counted from 0° to 360°, in the direction opposite to its rotation. Thus, the great dark marking, Syrtis Major, in longitude about 285°, arrives at the central meridian before Ismenius Lacus, in longitude 338°.

The easiest way to tell what part of Mars is turned toward the observer is to know the longitude on the central meridian at the time of observing. This information is available in the annual *American Ephemeris and Nautical Almanac*, from which the simplified listing of Table I is adapted. It gives the longitude of the central meridian of Mars at 7:00 p.m. Eastern standard time (EST) for every night in August and September. Double dates are used to avoid ambiguity. For other hours of observation, apply the appropriate correction from Table II, where corresponding times for the remaining United States time zones are also given.

For example, what is the longitude of the central meridian at 3 a.m. MST, on September 2nd? This is the night of September 1-2, and Table I gives a value of 16°. In Table II, 3 a.m. MST indicates a correction of +146°, and the longitude of the Martian central meridian is the sum of these, 162°. Reference to a Martian map shows that at this time Titanum Sinus will be nearly central on the disk.

Another example: When will Syrtis Major (longitude 285°) be on the central meridian September 20th, for an observer who uses Central standard time? The rule in this case is to subtract from the longitude of the marking the value taken out of Table I. Thus, 285° − 209° = +76°. Table II shows that a value of +73° corresponds to 11 p.m. CST, so that Syrtis Major will be central on the disk a little after that time on the night of September 20-21.

TABLE I

Night	*Aug.*	*Sept.*	*Night*	*Aug.*	*Sept.*
1-2	296°	16°	16-17	159°	244°
2-3	287	8	17-18	150	235
3-4	277	359	18-19	141	226
4-5	268	350	19-20	132	217
5-6	259	341	20-21	123	209
6-7	250	332	21-22	114	200
7-8	241	323	22-23	105	191
8-9	232	315	23-24	96	182
9-10	222	306	24-25	87	173
10-11	213	297	25-26	78	164
11-12	204	288	26-27	70	155
12-13	195	279	27-28	61	146
13-14	186	270	28-29	52	137
14-15	177	262	29-30	43	128
15-16	168	253	30-31	34	119
16-17	159	244	31-1	25	

TABLE II

EST	*CST*	*MST*	*PST*	*Correction*
p.m.	*p.m.*	*p.m.*	*p.m.*	
6	5	4	3	−15°
7	6	5	4	0
8	7	6	5	+15
9	8	7	6	+29
10	9	8	7	+44
11	10	9	8	+58
12	11	10	9	+73
1	12	11	10	+88
2	1	12	11	+102
3	2	1	12	+117
4	3	2	1	+132
5	4	3	2	+146
6	5	4	3	+160
7	6	5	4	+175
8	7	6	5	+190
9	8	7	6	+205
a.m.	*a.m.*	*a.m.*	*a.m.*	

Every drawing of Mars should be labeled with the date and time it was made. It will then always be possible to make a comparison with a map of the planet, using either tables such as given here or the more detailed data of the *American Ephemeris*. There is a map of Mars by E. M. Antoniadi on page 443 of this issue, showing approximate longitudes of many features.

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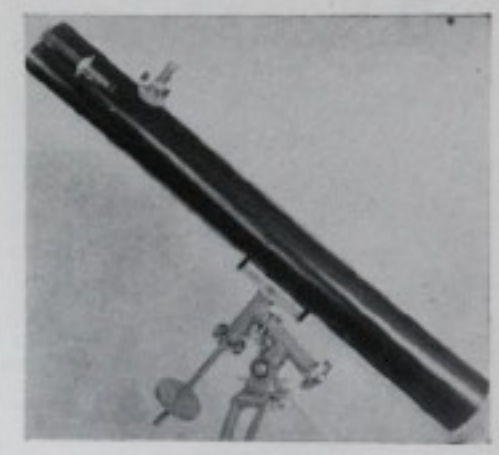

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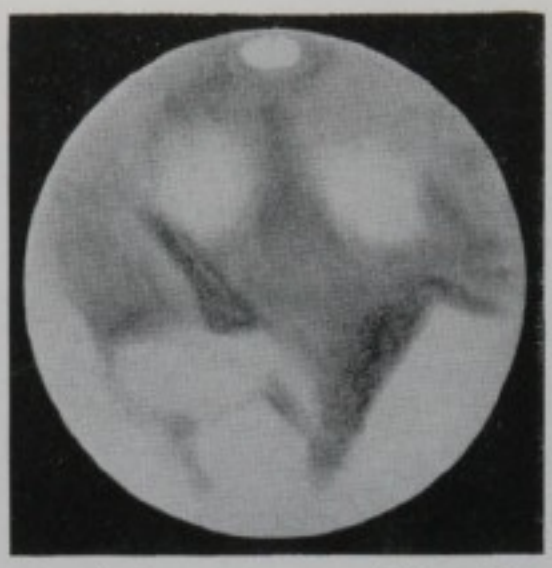


Longitude of central meridian 271°. Drawn by H. Wildey, October 2, 1941, with a 12½-inch reflector.

Longitude of central meridian 335°. Drawn by T. E. R. Phillips, September 24, 1941, with an 8-inch refractor.

mend magnifications of about 30 to 50 times the aperture in inches, for telescopes of moderate size. Thus, a 6-inch instrument would be used at 180x to 300x; unless the seeing is good enough to stand such powers, the observer should expect little. Careful focusing is necessary, preferably on the planet's limb or polar cap, or on some close double star.

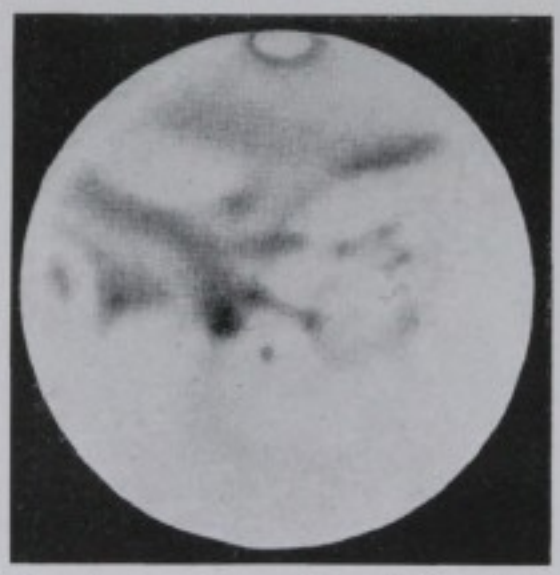
In any event, the beginning observer of Mars will certainly see much less than appears on a Martian map. Ordinarily, a person's first telescopic view of Mars shows it as a nearly featureless tiny disk. (Even at its closest, the planet appears smaller than the well-known lunar craters Aristarchus and Proclus.) The eye must gain experience; night-after-night scrutiny will finally enable the observer to make out details that were at first quite invisible to him. Much patience is needed at the telescope. Unless you are blessed with exceptionally fine seeing, you must watch the more-or-less blurred and trembling image of the planet for long periods, to catch the brief spells when the finer details become visible.

The six drawings of Mars with this article show its surface features as they successively come into view during the red planet's rotation. Used in connection with the tables, these drawings indicate the main markings visible in August and September of this year. They were made in 1941, when the orientation of the Martian axis with respect to the earth was nearly the same as at this year's opposition. All six drawings are by members of the Mars section of the British Astronomical Association, and are reproduced from the association's *Memoirs*, the 24th report of the Mars section, published in 1951. Some of their chief features are:

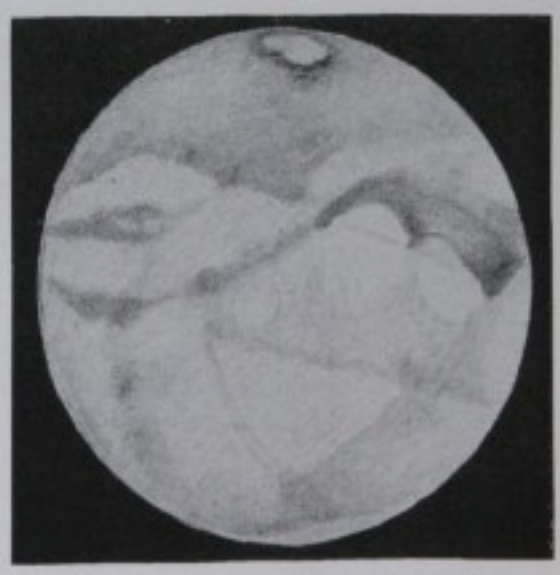
Central meridian longitude 271°. Syrtis Major is the large triangular patch at the lower right. It was drawn as early as 1659 by Huygens. The two large light areas a little above the center of the disk are Ausonia (left) and Hellas. The south polar cap is at the top, as in all these drawings.

Longitude 335°. Syrtis Major is now near the left edge. The elongated nearly horizontal dark marking is Sinus Sabaeus; its two-pronged right end is Sinus Meridiani, so called because it is very near the zero meridian of Martian longitude. The light strip running along the upper (southern) edge of Sinus Sabaeus is Deucalionis Regio.

Longitude 58°. The very dark region near the center is Aurorae Sinus; midway



Longitude of central meridian 58°. Drawn by F. J. Hargreaves, October 21, 1941, with a 14½-inch reflector.



Longitude of central meridian 113°. Drawn by C. F. Du Martheray, September 13, 1941, with a 5½-inch refractor.

Longitude of central meridian 163°. Drawn by M. A. Ellison, October 11, 1941, with a 6-inch refractor.

Longitude of central meridian 230°. Drawn by M. A. Ellison, October 2, 1941, with a 6-inch refractor.

between this and the left edge is the dusky triangle Margaritifer Sinus, the Gulf of Pearls. Nearly an inch below the top edge of the engraving and about ¾ inch from the right edge is a wedge-shaped patch with three darker nuclei. This is Solis Lacus, which has undergone extraordinary changes in structure and conspicuousness since Schiaparelli charted it in 1877.

Longitude 113°. Solis Lacus is about to be carried around the left edge of the disk by Martian rotation; here it is recognizable as the pupil of the "eye of Mars." The white above the pupil is Thaumasia; the dark lower lid is Tithonius Lacus. Centered about half an inch below the polar cap is the dark Aonius Sinus; below it and to the right, the dark elephant's trunk is Sirenum Sinus, which continues leftward across the center of the disk as the canal Araxes.

Longitude 163°. Sirenum Sinus now appears as the left-hand (eastern) end of a huge dark marking, Mare Sirenum, which is twice as large as our Caspian Sea. Its northern (lower) tip is Titanum Sinus, one of the easiest Martian features to detect in a small telescope.

Longitude 230°. In the middle of the disk, Mare Cimmerium is dark and prominent. From its tip the canal Adamas runs downward to the right to Nodus Alcyonius, the neighborhood of the remarkable new marking discussed by Tsuneo Saheki on page 442 of this issue. Near the right edge, Syrtis Major is just coming into view; it is connected to Nodus Alcyonius by the strongly curved canal Thoth-Nepenthes—perhaps the easiest of all the canals to recognize in amateur telescopes.

J. A.

MARS OBSERVING EXPEDITION IN CALIFORNIA

The California Academy of Sciences is placing a temporary observatory equipped with a 12½-inch Cassegrainian reflector atop Junipero Serra Peak in Monterey County for the Mars opposition. This isolated, 5,862-foot mountain is 13 miles west of King City and only 12 miles from the Pacific Ocean; it is the highest point in the southern Coast Range. The seeing is expected to be very good whenever the prevailing winds bring dust-free air in from the ocean.

The instrument has been placed on a solid mounting, for which foundation holes were dug. Visual and photographic attachments and a photoelectric photometer have been designed and constructed in the academy's instrument shop. The station is being manned by the undersigned during August and September.

By photographing Mars through blue and red filters, we hope to detect the "blue clearing" or sudden changes in the transparency of the planet's atmosphere. For visual work, good seeing should permit magnifying Mars' disk 600 times or more to observe the formation and drift of clouds in its atmosphere. The movements of such clouds, if detected, will be measured with a filar micrometer, in order to gain information on the Martian winds.

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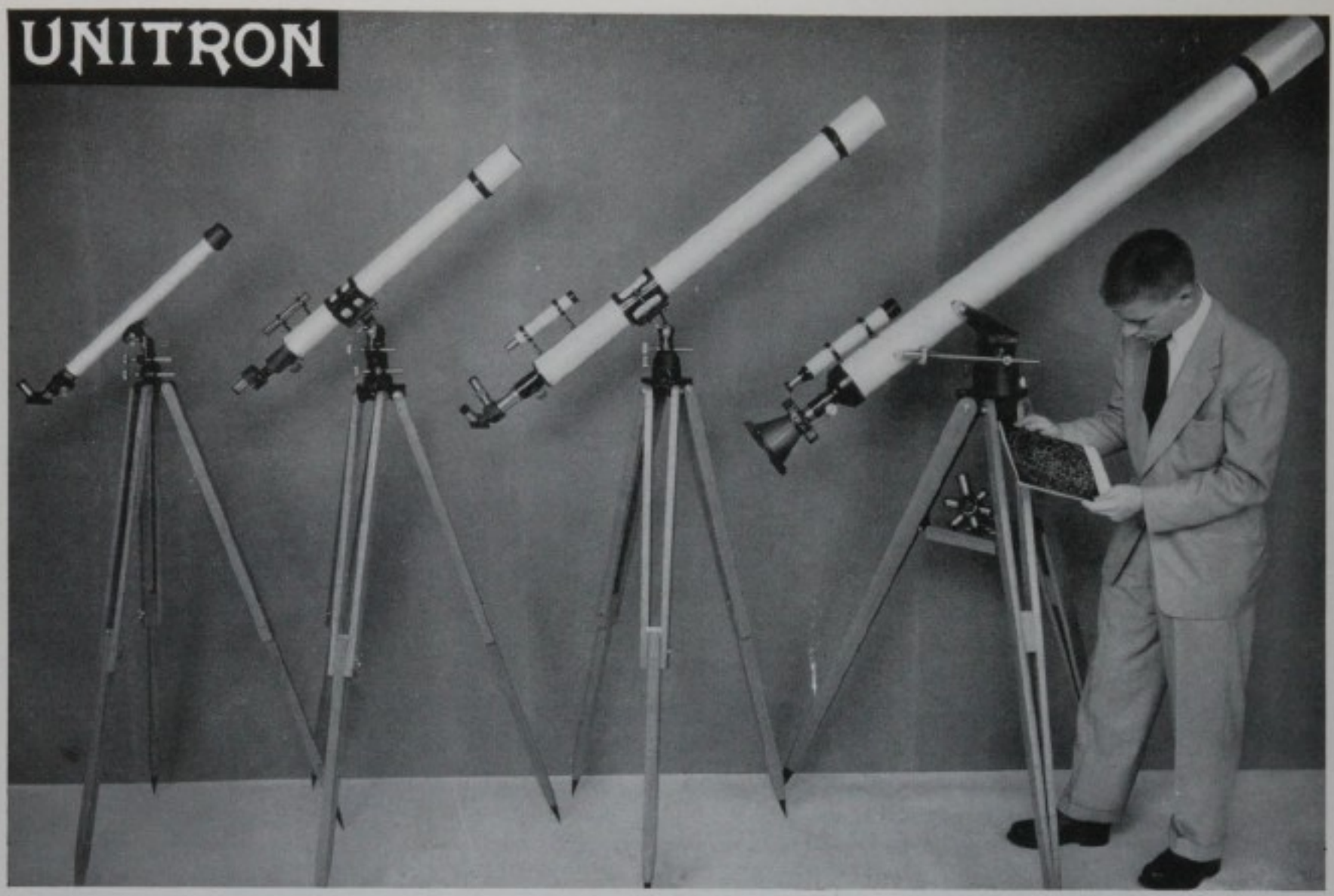
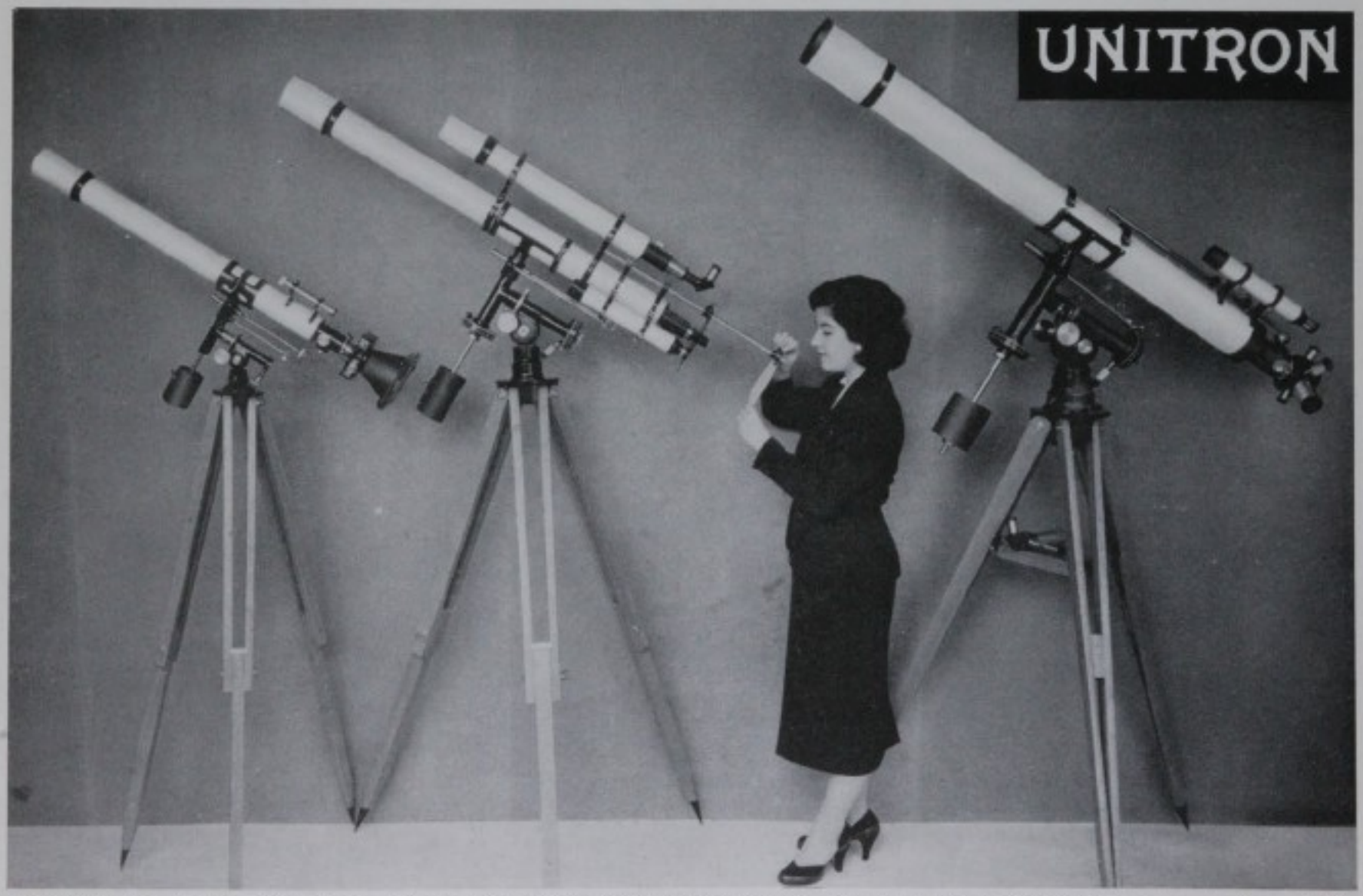


UNITRON Altazimuth Refractors: left to right, 1.6″ (with star diagonal), 2.4″ (with erecting prism system), 3″ (with DUETRON double eyepiece), and 4″ (with astro-camera and with UNIHEX on the shelf).



UNITRON Equatorial Refractors: left to right, 2.4″ (with astro-camera), 3″ Photo-Equatorial (with sun screen), and 4″.

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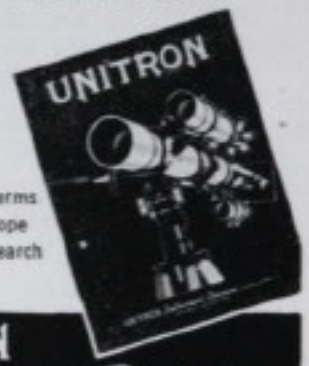

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SUNSPOT NUMBERS

May **1**, 101, 78; **2**, 96, 93; **3**, 107, 138; **4**, 134, 169; **5**, 138, 158; **6**, 118, 162; **7**, 155, 162; **8**, 166, 186; **9**, 154, 180; **10**, 146, 178; **11**, 143, 175; **12**, 130, 163; **13**, 118, 142; **14**, 110, 133; **15**, 95, 110; **16**, 86, 122; **17**, 107, 132; **18**, 131, 144; **19**, 119, 136; **20**, 131, 127; **21**, 117, 144; **22**, 108, 119; **23**, 75, 82; **24**, 80, 102; **25**, 95, 103; **26**, 94, 120; **27**, 105, 115; **28**, 119, 137; **29**, 125, 136; **30**, 121, 146; **31**, 111, 123. Means for May: 117.3 American; 136.0 Zurich.

Above are given the date, the American number, then the Zurich number. These are observed mean relative sunspot numbers, the American computed by D. W. Rosebrugh from AAVSO Solar Division observations, the Zurich numbers from Zurich Observatory and its stations in Locarno and Arosa.

J. Mergentaler has reported in the Polish journal *Urania* the following monthly sunspot numbers for 1955, based upon observations made in Poland: January, 22.0; February, 21.4; March, 4.0; April, 8.4; May, 23.4; June, 24.0; July, 22.6; August, 38.4; September, 41.0; October, 53.3; November, 77.4; December, 60.4.

AUGUST METEORS

The Perseid meteors, richest of those showers that recur each year, will be observable under very favorable conditions this year because moonlight will not interfere. The first Perseids appear late in July, and increase in number until August 12th, after which they become steadily fewer. On any one night, Perseids are more numerous after midnight, as the radiant point climbs higher in the sky. At the date of maximum, 50 meteors per hour may be counted before dawn, if skies are clear. The moon sets before midnight, as the first quarter phase on August 13th is in Libra.

These meteors are swift, many leaving trains, and a large proportion of them are 1st magnitude or brighter. The radiant is at right ascension 3^h 04^m, declination +57°, north of Gamma Persei, at the date of maximum activity. E. O.

PREDICTIONS OF BRIGHT MINOR PLANET POSITIONS

Urania, 30, 9.5. July 26, 22:32.8 −8-18. August 5, 22:27.1 −8-36; 15, 22:19.1 −9-07; 25, 22:09.8 −9-46. September 4, 22:00.4 −10-27; 14, 21:52.2 −11-01.

Metis, 9, 8.8. August 15, 23:21.7 −14-19; 25, 23:14.3 −15-24. September 4, 23:05.2 −16-27; 14, 22:55.7 −17-19; 24, 22:46.9 −17-52. October 4, 22:40.1 −18-04.

Harmonia, 40, 8.9. August 15, 23:39.7 −9-32; 25, 23:33.5 −10-39. September 4, 23:25.3 −11-51; 14, 23:16.0 −12-57; 24, 23:07.2 −13-49. October 4, 23:00.0 −14-19.

After the asteroid's name are its number and the magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1950.0) for 0^h Universal time. In each case the motion of the asteroid is retrograde. Data are supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

VARIABLE STAR MAXIMA

August 2, T Aquarii, 204405, 7.9; 4, S Pegasi, 231508, 8.0; 10, R Canum Venaticorum, 134440, 7.7; 12, Z Ursae Majoris, 115158, 6.6; 15, X Centauri, 114441, 7.8; 21, RS Herculis, 171723, 8.0; 22, R Lyncis, 065355, 7.9; 22, SS Virginis, 122001, 6.9; 24, R Indi, 222867, 8.0.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted magnitude

MOON PHASES AND DISTANCE

New moon	August	6, 11:25
First quarter	August	13, 8:45
Full moon	August	21, 12:38
Last quarter	August	29, 4:13
New moon	September	4, 18:57

	August	Distance	Diameter
Perigee	5, 21^h	222,400 mi.	33′ 23″
Apogee	18, 16^h	252,200 mi.	29′ 26″
	September		
Perigee	3, 4^h	224,300 mi.	33′ 06″

UNIVERSAL TIME (UT)

TIMES used on the Observer's Page are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown.

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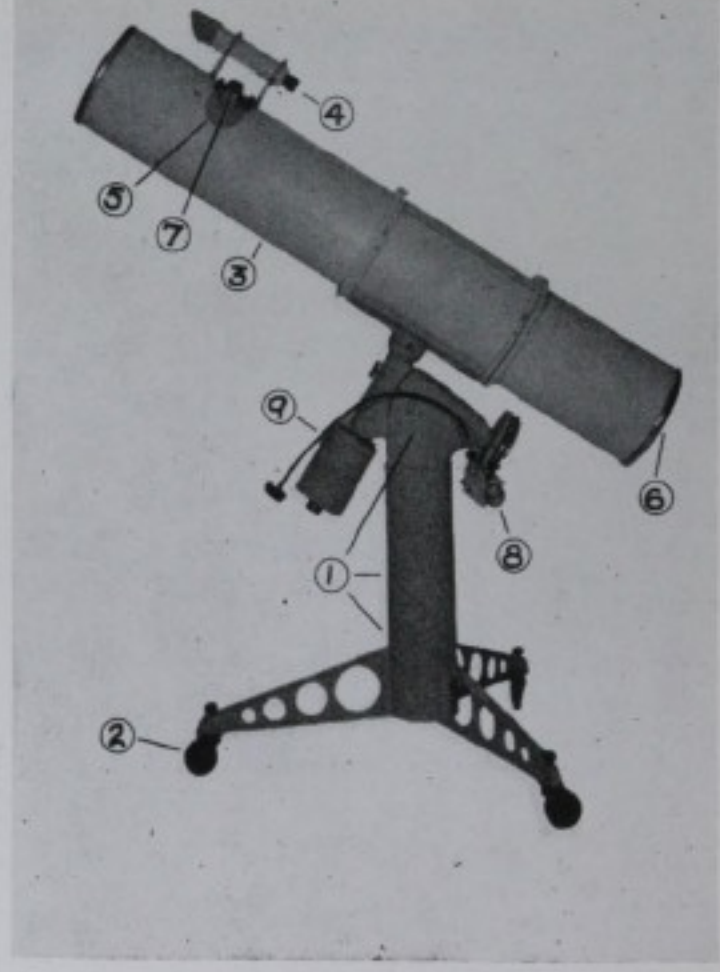

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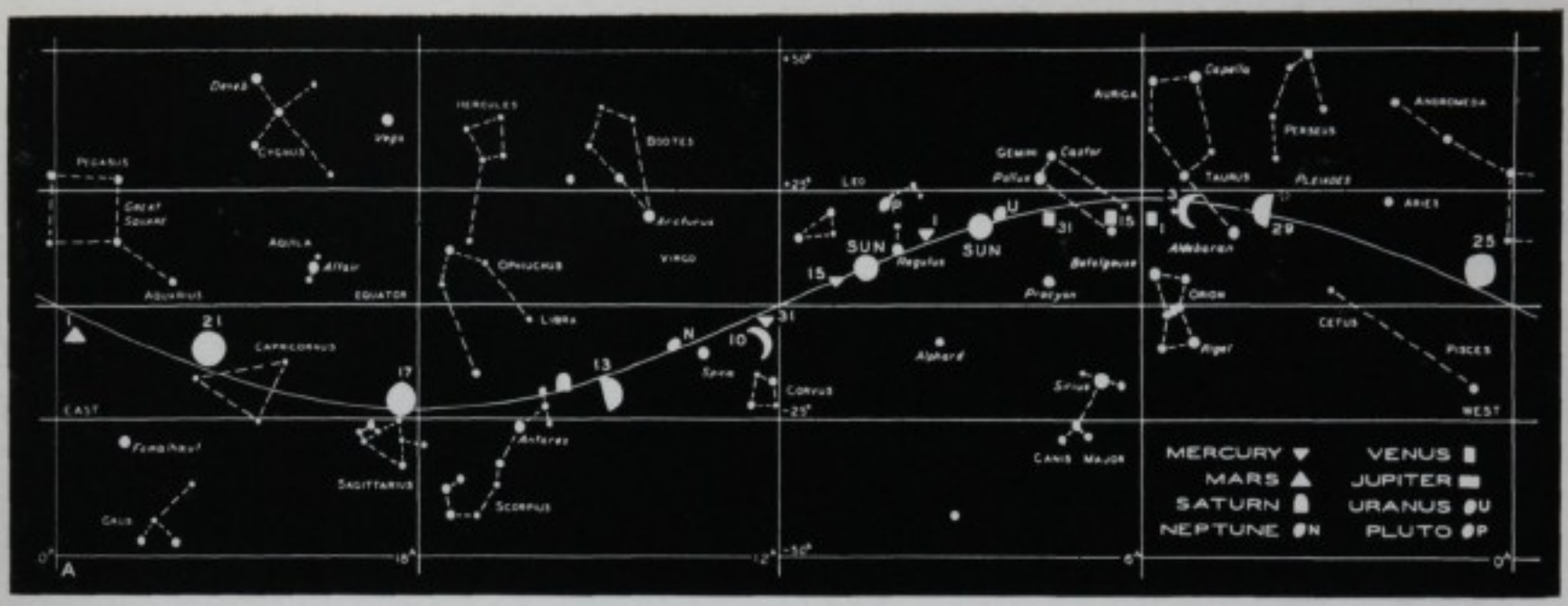

THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month and for other dates shown.

Mercury remains in the evening sky all month, but poorly placed for viewing from northern latitudes. At greatest elongation on August 31st, when 27° 13′ east of the sun, Mercury sets only about one hour after the sun. An interesting conjunction occurs on August 9th, as the planet passes 10′ south of Jupiter. Mercury will then be of magnitude −0.3 and Jupiter −1.3, the two planets setting one hour after sunset.

Venus appears brilliant in the morning sky, rising about 3½ hours before the sun during the latter part of August. On the 31st, Venus is at greatest elongation, in Gemini, and 45° 55′ west of the sun. This dazzling white object shines at magnitude −4.1 in mid-August, when a telescope will reveal a disk 29″ in diameter and 40 per cent illuminated.

This planet may be seen in the daytime, particularly on September 1st, when near the moon. Conjunction occurs at 12:29 UT, with Venus 1° 08′ north of the moon.

Mars, rising 1½ hours after sunset in midmonth, dominates the midnight sky with its red brilliance. The planet brightens from a magnitude of −1.8 to −2.5 through August. Located in Aquarius, Mars begins retrograde (westward) motion on the 11th, prior to opposition next month. On August 21st it passes the perihelion point in its orbit, and the next three months will be unusually favorable for telescopic observations. The Martian diameter is 22″.6 on August 15th.

Jupiter is low in the western sky after sunset, and disappears into the sun's glare early in August. Its conjunction with Mercury on the 9th is described above.

Saturn, visible only during evening hours, comes to eastern quadrature with the sun on August 19th. The planet is in Libra, and is of magnitude +0.7. On the 15th, the ring system will be inclined 23°.8, with the northern face in view.

Uranus is in the morning sky, rising shortly before dawn begins.

Neptune is in Virgo, and observable only during early evening hours. E. O.

CORRECTION

In the chart of Mars' path on page 377 of the June issue, the label υ (upsilon) used for three stars in Pegasus, Aquarius, and Pisces, should be changed to θ (theta) in each case. Gary E. Caldwell, Mount Pleasant, Iowa, has called attention to these errors.

MINIMA OF ALGOL

August 3, 12:34; 6, 9:23; 9, 6:12; 12, 3:00; 14, 23:49; 17, 20:37; 20, 17:26; 23, 14:14; 26, 11:03; 29, 7:52. September 1, 4:40; 4, 1:29; 6, 22:17; 9, 19:06.

These minima predictions for Algol are based on the formula in the 1953 *International Supplement* of the Krakow Observatory. The times given are geocentric; they can be compared directly with observed times of least brightness.

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OUTER-SPACE GEMS? Yes! Free information about these oddities, also rare, beautiful minerals and gemstones of this earth. Rare Gem and Mineral Co., 5880 Hollywood Blvd., Hollywood 28, Calif.

BINOCULAR MOUNT, altazimuth, hard aluminum alloy, highly resistant to weather. Screw into top of stepladder, fence post, etc. Rigid and solid. Fits any binocular with ¾″ clearance on centerpost. Only $5.00 postpaid. Anaheim Astronomy, 536 Concord Place, Anaheim, Calif.

WILL PURCHASE 16″ pyrex mirror blank with or without glass tool. Write giving specifications and your price to Edgar Everhart, Wormwood Hill, Mansfield Center, Conn.

SETTING CIRCLES, 8″ printed. Precise fine markings, 720 divisions, beautifully numbered, reinforced pilot hole in exact center. Guaranteed perfect. Complete detailed instructions for accurate mounting and lining up scope for use of circles. $6.00 per pair. B. A. Stevens, 2011 LaMesa, Dodge City, Kans.

PROFESSIONALS and Amateurs Attention: Telescope objectives 3-3/16″ diameter, achromatic, coated, 24½″ focal length in threaded brass cell, excellent for telescopes and finders, $16.00. Height-finder objectives 2-3/64″ diameter, achromatic, coated, approximately 9″ focal length in threaded metal cell, $5.00 each. 7 x 50 binocular eyepieces, spiral focusing, coated eye lens, $3.00 each. Red filters, 1-3/16″ diameter, in slip-on brass cells, 6 for $1.00. Tank periscope right-angle prisms 1½ x 1½ x 2⅛ x 5¼ inches long, in metal and plastic housing, 2 for $1.50. Surplus stock is limited. Express or parcel-post paid in U. S. Satisfaction or money refunded. Charles E. Roberts, 730 4th St., Fremont, Ohio.

ASTRONOMICAL TELESCOPES, Monolux Space Rover, $68.50, easily worth $110.00. Book bargains. Rasmussen and Reece, Amsterdam, N. Y.

SACRIFICE AT $400.00, my personal 12″ scope. Will hand grind to order mirrors up to 10″. Herb Doughty, 611 Prospect Ave., Lima, Ohio.

SETTING CIRCLES, photo printed! 5″—$4.50 to 8″—$5.75 per pair. Declination and hour angle divided to half degrees and two minutes, respectively. Instructions included. Kits later! 6″ mirror, 75″ focal length, $15.00. Gerald N. Rote, 82 Floradale, Tonawanda, N. Y.

TAPE RECORDING of "Introductory Planetarium Lecture" on basic constellations, etc., 15 minutes. Recorded 7½″ single or dual track. Check or money order for $5.00 to School of Broadcasting, 1307 Ridgelake Drive, Metairie, La.

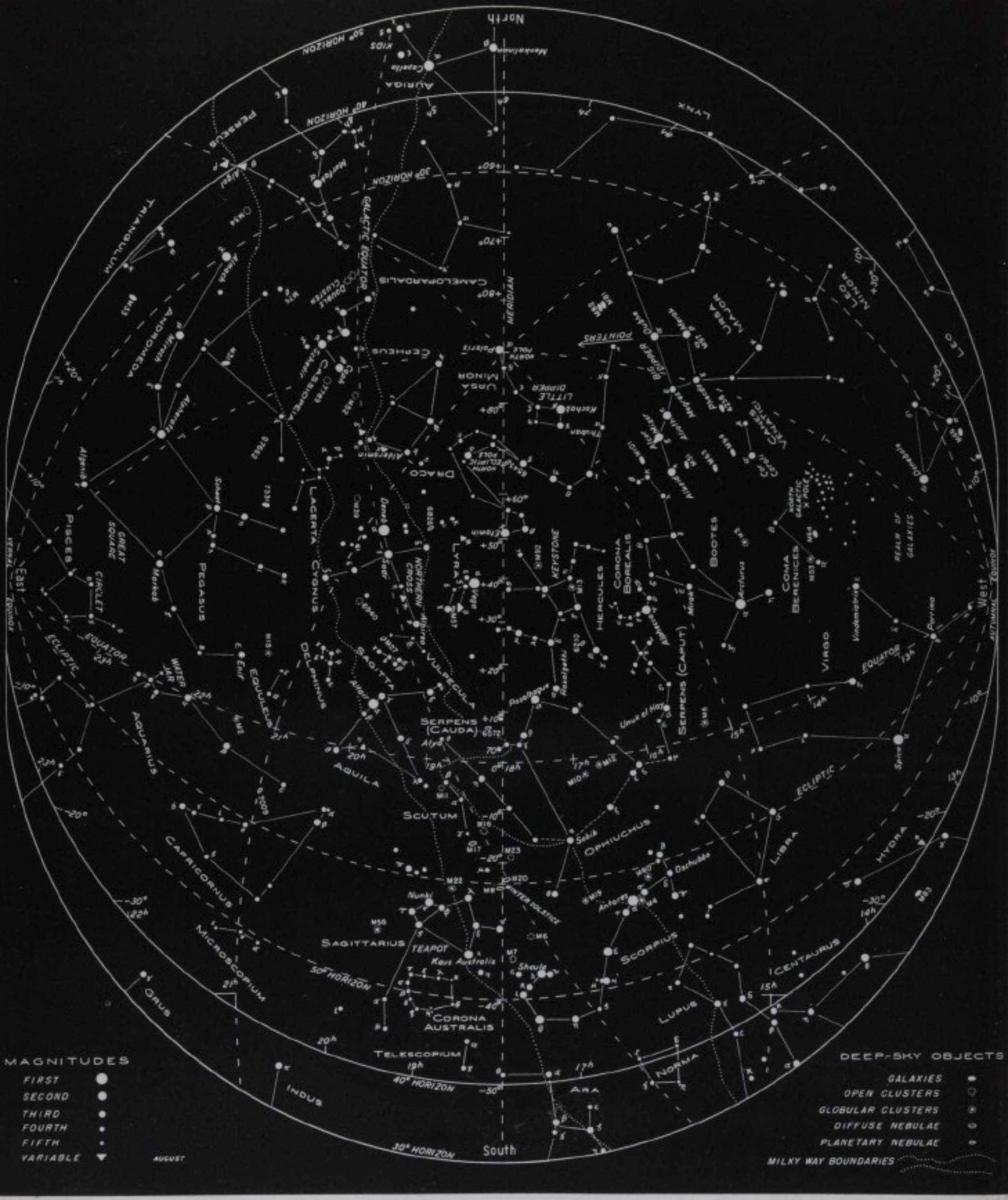
WANTED: 6″ refractor objective. Will pay cash. Age or condition does not matter. Give full particulars. Bill Ashdowne, 18450 Grand River, Detroit 23, Mich.

MOUNTED: 5″ and 6″ refractor objectives of first quality, $220.00 and $325.00. 4″ edged blanks, $20.00. Correspondence invited. Earl Witherspoon, Sumter, S. C.

METEORITES reach the earth from interplanetary space. Use for research, lectures, and demonstrations. Arizona crater, $3.00, $5.00, $10.00. Odessa, Texas, $2.00, $3.00, $5.00. Scientific Laboratory, 2846 Oakley Ave., Baltimore 15, Md.

8″ REFLECTOR f/10, heavy equatorial mount, eyepieces, finder, slow-motion drive, excellent optics. $300.00. Information and photos from Henry G. Dumas, 454 Forsyth St., Barnesville, Ga.

MASTER CLOCK, genuine Synchronome with seconds dial, in mahogany case. Like new condition. Photos available. $300.00. B. Wacek, 2901 Remington Ave., Baltimore 11, Md.



STARS FOR AUGUST

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of August, respectively; also, at 7 p.m. on September 7th. For other dates, add or subtract ½ hour per week.

An exercise for those who like to know all their star groups thoroughly is to identify every charted star in the large but relatively dim constellations of Hercules, Ophiuchus, and Serpens, which are well placed for observation near the meridian these summer evenings.

Brandon Astronomical Objectives

Each 4-inch and 3-inch Brandon objective is shipped already mounted in a cell, ready to attach to your own tube of aluminum, brass, steel, or plastic.

NOW ANY AMATEUR CAN MAKE HIS OWN REFRACTOR!

As every exacting telescope user knows, the heart of a telescope is its objective lens or primary mirror. It is difficult to make the four surfaces of an achromatic two-element lens, and few amateurs tackle the task. But the mounting of a mirror and the maintenance of a reflecting telescope are often costly and time-consuming, while a refractor can be constructed easily and inexpensively with one of our astronomical objectives. The finished instrument requires little attention over the years and is always worth its original cost.

Therefore, if you want to get the most telescope for your time and money, buy one of our first-quality objectives and mount it yourself simply by attaching the cell to a tube of the proper diameter and length. The other end of the tube should carry a smaller sliding tube which in turn has an eyepiece holder. Focusing may be done by sliding one tube in the other, by rack and pinion, or by a spiral-focusing mechanism.

You have no diagonal support problem, no diagonal or prism to shake loose, no complicated aligning, no diffraction patterns of diagonal and support. Even the five-foot tube assembly of a 4-inch refractor is light and easy to mount as an altazimuth or equatorial instrument (see *Amateur Telescope Making—Book Two*, pages 192-211). It can be put on a tripod that is easily portable or on a permanent pier. Refractors are noted for the ease with which they can be set up and taken down; they pack easily into boxes for shipment and travel. The refractor lens provides a large field of excellent definition suitable for all kinds of eyepieces and for direct or projection photography. Either of our objectives, combined with any of our seven eyepieces, gives a wide range of powers:

Size of eyepiece:	4-mm.	6-mm.	8-mm.	12-mm.	16-mm.	24-mm.
3-inch f/15 lens:	290x	195x	145x	95x	75x	50x
4-inch f/15 lens:	390x	260x	195x	130x	95x	65x

When atmospheric conditions permit, you can take advantage of the well-known resolving power of the refractor. You have the perfect instrument for observing details on the planets, such as Mars when nearest to us this summer. Each Brandon lens is rigidly tested for its resolution of double stars before being sold. Brandon objectives enjoy an enviable reputation among professional and amateur astronomers for their fine performance. Check these features:

1. Superior optical design utilizing a larger air separation. Color corrected on C and F and hand corrected to reduce residuals to a minimum. Completely free of coma.

2. Glass-air surfaces magnesium-fluoride coated, increasing light transmission approximately 10 per cent.

3. Quality optical glass precision annealed and held to one ring test-plate match.

4. Cell made to precision tolerances and suitably coated to prevent stray light reflections. Each cell engraved with effective focal length and serial number.

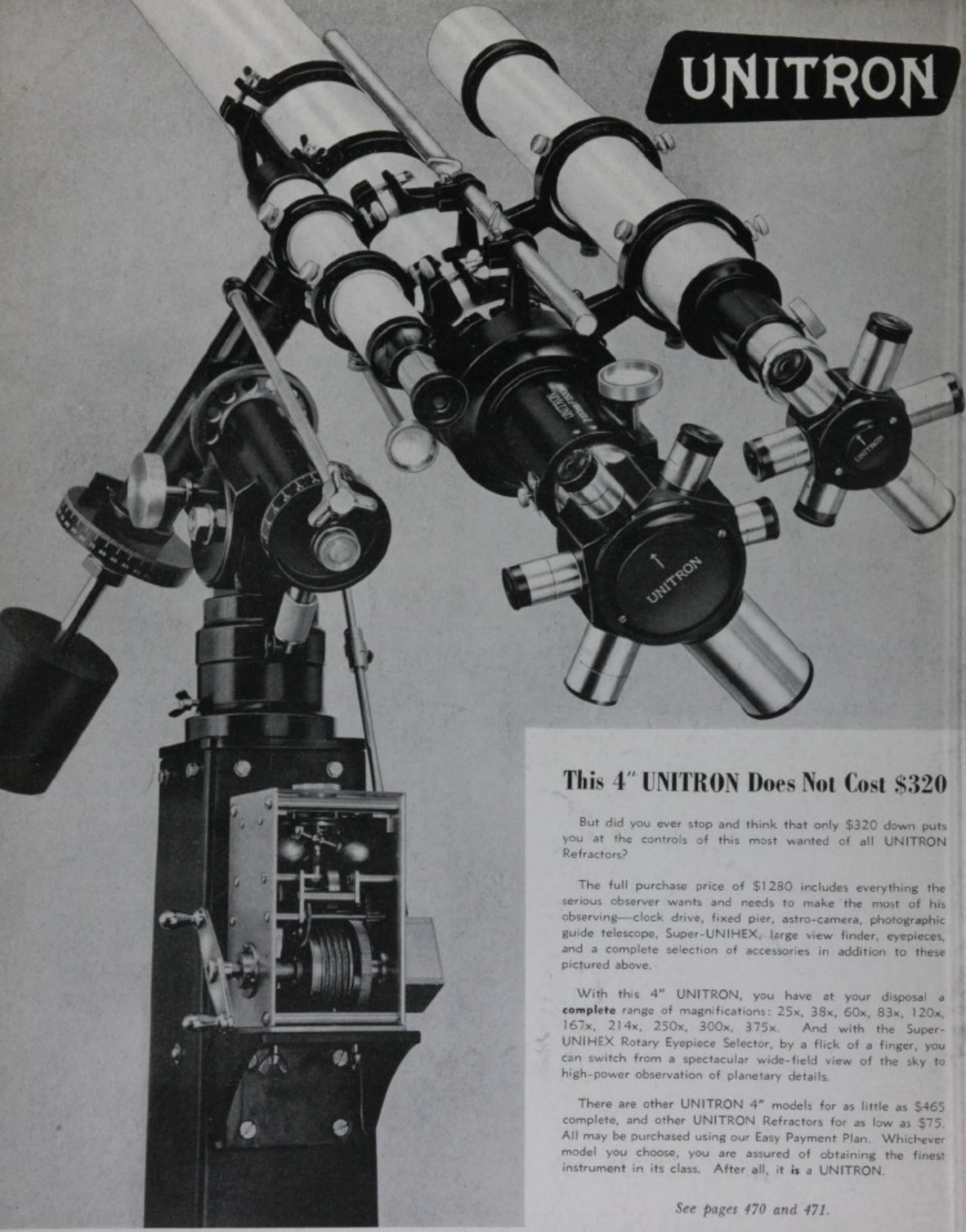
These objectives are supplied with cells and rigidly tested on double stars for resolving power before being sold:

3″ Clear Aperture	**45.8″ Focal Length**	**$ 62.00**
4″ Clear Aperture	**61.2″ Focal Length**	**$138.00**

Your order, accompanied by check or money order, will be filled immediately and sent air-mail insured.
Send self-addressed 6¢ (air mail) stamped envelope for other dimensions. Satisfaction guaranteed, or your money will be refunded.

Brandon Instruments

GUAYNABO, PUERTO RICO



This 4" UNITRON Does Not Cost $320

But did you ever stop and think that only $320 down puts you at the controls of this most wanted of all UNITRON Refractors?

The full purchase price of $1280 includes everything the serious observer wants and needs to make the most of his observing—clock drive, fixed pier, astro-camera, photographic guide telescope, Super-UNIHEX, large view finder, eyepieces, and a complete selection of accessories in addition to these pictured above.

With this 4" UNITRON, you have at your disposal a **complete** range of magnifications: 25x, 38x, 60x, 83x, 120x, 167x, 214x, 250x, 300x, 375x. And with the Super-UNIHEX Rotary Eyepiece Selector, by a flick of a finger, you can switch from a spectacular wide-field view of the sky to high-power observation of planetary details.

There are other UNITRON 4" models for as little as $465 complete, and other UNITRON Refractors for as low as $75. All may be purchased using our Easy Payment Plan. Whichever model you choose, you are assured of obtaining the finest instrument in its class. After all, it **is** a UNITRON.

See pages 470 and 471.

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